Synopsis of Research

Conducted under the 1998/99
Northern Contaminants Program

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Synopsis of Research Conducted under the 1998/99 Northern Contaminants Program

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The views, conclusions and recommendations expressed herein are those of the authors and not necessarily those of the Department.

FOREWORD

This report summarizes the results of research and monitoring studies on contaminants in northern Canada, and related activities conducted under the auspices of the 1998/99 Northern Contaminants Program. The projects cover all aspects of the northern contaminants issues, including: sources and transport; contamination of marine, freshwater and terrestrial ecosystems; human exposure through diet and related health implications; communication activities and education of northern residents; and international initiatives addressing the global aspect of the problem.

These projects were evaluated by the Technical and Science Managers Committees on Contaminants in Northern Ecosystems and Native Diets to ensure that they supported the overall Northern Contaminants Program objectives.

A list of addresses for the project leaders is given in Appendix I.

PRÉFACE

Ce rapport résume les résultats de recherches portant sur les contaminants et d'études sur la surveillance des contaminants dans le Nord canadien, et activités connexes. Ces études ont été menées dans le cadre du Programme de lutte contre les contaminants dans le Nord, 1998/99. Ces projets représentent tous les aspects du problème des contaminants, incluant les sources et le transport, la contamination des écosystèmes aquatiques (eaux douces et eaux salées) et terrestres, l'exposition de l'organisme humain en raison de son régime alimentaire et ses effets sur la santé, la communication avec les résidents du Nord et leur éducation, et les initiatives internationales abordant l'aspect global du problème.

Les comités de gestionnaires techniques et scientifiques sur les contaminants dans les écosystèmes du Nord et dans les régimes alimentaires des Autochtones ont examiné ces projets afin de s'assurer qu'ils répondent à l'ensemble des objectifs du Programme de lutte contre les contaminants dans le Nord.

Vous trouverez à l'appendice 1 une liste des gestionnaires de projet.

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INTRODUCTION

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in wildlife species that are important to the traditional diets of northern Aboriginal peoples. Early studies indicated that there was a wide spectrum of substances – persistent organic pollutants (POPs), heavy metals, and radionuclides – many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem. The Program's key objective is *to reduce and, where possible, eliminate contaminants in northern traditionally harvested (country) foods while providing information that assists informed decision making by individuals and communities in their food use*.

Under the first phase of the NCP (NCP-I), research was focussed on gathering the data required to determine the levels, geographic extent, and source of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. The data enabled us to understand the spatial patterns and temporal trends of contaminants in the North, confirmed our suspicions that the major sources of contaminants were other countries, and were an important element in our assessment of human health risks resulting from contaminants in traditional foods (including consideration of benefits from continued consumption of those foods). Results generated through NCP-I are synthesized in the *Canadian Arctic Contaminants Assessment Report* (CACAR: Jensen *et al.* 1997).

Extensive consultations were conducted in 1997/98 to find the common elements between the concerns and priorities of northern communities and the scientific needs identified as critical for addressing the issue of contamination in Canada's North. As a result, priorities for future research are based on an understanding of the species that are most relevant for human exposure to contaminants in the North, and geographic locations and populations that are most at risk.

In 1998/99, the NCP began a second phase (NCP-II), which will continue until 2002/03. NCP-II supports research designed to answer questions about the impacts and risks to human health that may result from current levels of contamination in key Arctic food species. To ensure a balanced assessment of the risks, an emphasis is placed on characterizing and quantifying the benefits associated with traditional diets. Communications activities are also emphasized and supported under NCP-II. Under the leadership of the northern Aboriginal organizations, the dialogue between northerners and the scientific community, which was initiated in NCP-I, continues to build awareness and an understanding of contaminants issues, and helps to support the ability to deal with specific contaminant issues at the local level.

In addition, the NCP effort to achieve international controls of contaminants will remain strong in NCP-II. The legally binding LRTAP protocol has now been successfully negotiated and was signed by 34 countries (including Canada) at the UN ECE Ministerial Conference in Aårhus, Denmark in June 1998. Canada ratified this agreement in December 1998. Negotiations for a legally binding global instrument on POPs under the United Nations Environment Programme have begun, a new phase of the circumpolar Arctic Monitoring and Assessment Programme (AMAP) is under way, and the Canada/Russia Program on Scientific and Technical Cooperation in the Arctic and the North is continuing. NCP-II will continue to generate the data that allows Canada to play a leading role in these initiatives.

The NCP is directed by a management committee that is chaired by the Department of Indian Affairs and Northern Development, and which includes representatives from the five northern Aboriginal organizations (Inuit Tapirisat of Canada, Inuit Circumpolar Conference, Dene Nation, Métis Nation, and the Council for Yukon First Nations), the Yukon, Northwest Territories and Nunavut Territorial Governments, and four federal departments (Environment, Fisheries and Oceans, Health, and Indian Affairs and Northern Development). The management committee is responsible for establishing NCP policy and research priorities and for final decisions on the allocation of funds. There are two regional contaminants committees in the Yukon and the Northwest Territories that support this national committee, and a similar committee will soon be formed in Nunavut. Funding for the NCP-II's $5.4 million annual research budget comes from the Treasury Board and the four participating federal departments.

This report provides a summary of the research and activities funded by the Northern Contaminants Program in 1998/99, the first year of NCP-II. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 1998/99 fiscal year. The report is divided into five chapters that reflect the broad scope of the NCP: Sources, Pathways and Fate of Contaminants; Ecosystem Contaminant Uptake and Effects; Human Health; Education, Communications and Community-based Strategies; and International Policy and Program Coordination. Projects that are reported in this Synopsis of Research will be presented at the 9th Annual Northern Contaminants Program Results Workshop, to be held in White Rock, BC, September 29 – October 1, 1999.

Sources, Pathways and Fate of Contaminants

NORTHERN CONTAMINANTS AIR MONITORING: A KEY ELEMENT OF NORTHERN CONTAMINANT PATHWAYS STUDIES

Project Leader: Len Barrie, Atmospheric Environment Service (AES), Downsview, ON

Project Team: Renata Bailey, Terry Bidleman, Ken Brice and Desirée Toom-Sauntry (AES); B. Billick, B. Grift, Lyle Lockhart and Gary Stern (Freshwater Institute (FWI), Winnipeg, MB); Donna Dougherty and Phil Fellin (Conor Pacific); Chris Halsall (University of Lancaster); Derek Muir (Environment Canada)

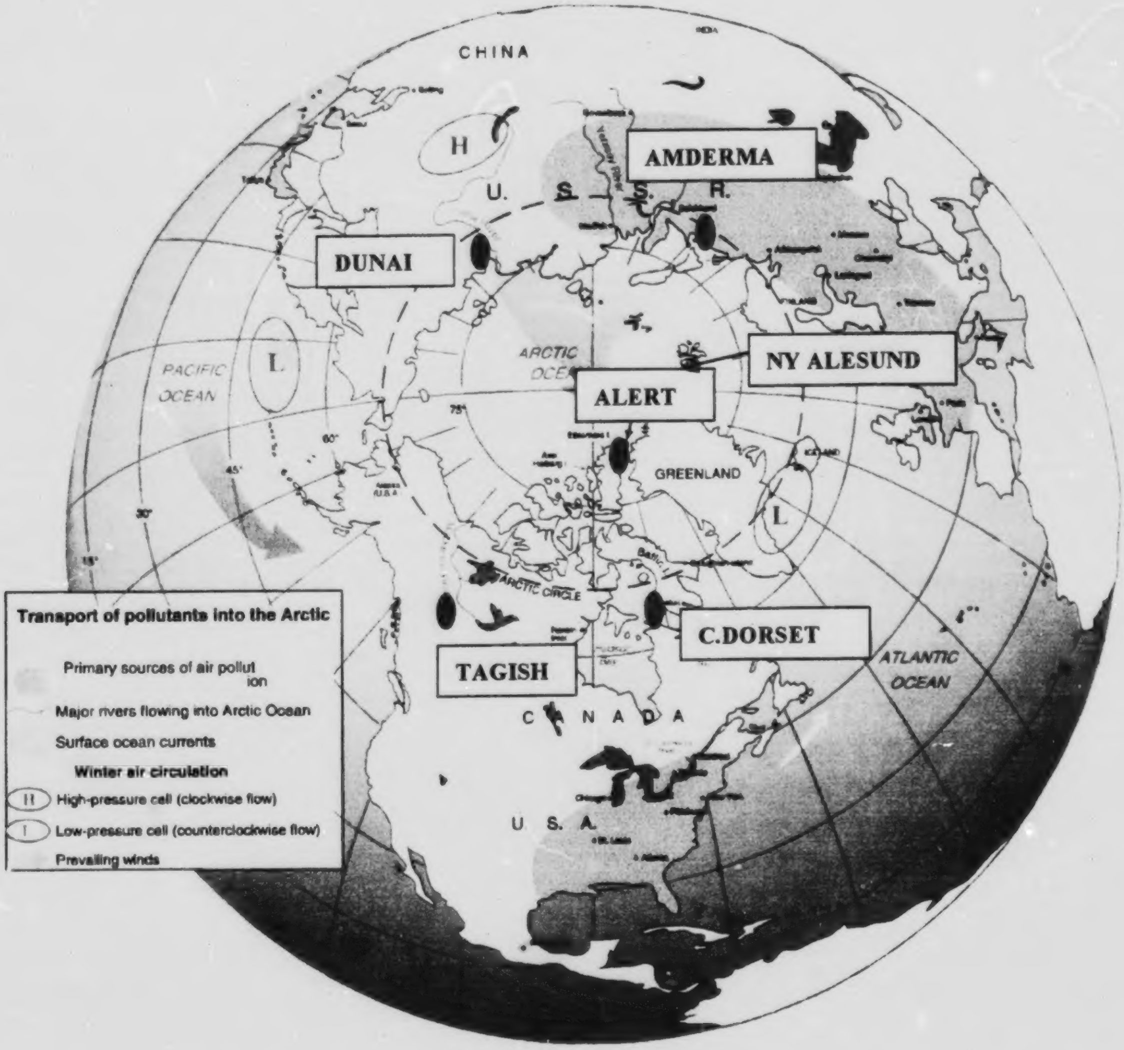
OBJECTIVES

1. To measure and understand the occurrence and trends of selected organochlorines (OCs) and polycyclic organic hydrocarbons (PAHs) in the Arctic atmosphere.
2. To provide insight into contaminant pathways (i.e. sources, transport, transformation and removal processes).
3. To enable validation of models of contaminants in the northern environment with atmospheric observations.
4. To maintain an archive of organic extracts of Arctic air samples for retrospective investigation for "contaminants of the future" (e.g. new generation pesticides, degradation products of pesticides currently not recognized as contaminants or contaminants that were undetectable previously by less modern analytical methods, etc.).
5. To operate a major long-term trends measurement station for the Arctic Monitoring and Assessment Programme (AMAP) at Alert, NWT (in operation since 1992) in parallel with a western Russian Arctic station funded by the \ Canadian International Development Agency and the Department of Indian and Northern AffairsDepartment of Foreign Affairs and International Trade.

DESCRIPTION

Since January 1992, measurements of airborne persistent organic pollutants (POPs) including herbicides, pesticides, synthetic industrial compounds and PAHs have been made on a weekly basis in the Canadian and Russian Arctic (Figure 1). This report focuses on OC results from Tagish, Yukon and is extracted from Bailey *et al.* (1999).

Concentrations of hexachlorocyclohexanes (HCHs), chlordane, DDT, and other OC pesticides were measured in ambient air samples on a weekly basis between December 1992 and January 1995 at Tagish, Yukon, Canada. Mean concentrations of chlordanes and DDT were <1.5 $\text{pg}\cdot\text{m}^{-3}$, while γ-HCH and α-HCH mean concentrations were ~10 $\text{pg}\cdot\text{m}^{-3}$ and ~65 $\text{pg}\cdot\text{m}^{-3}$, respectively (Table 1). Other OCs were observed at mean concentrations of <6 $\text{pg}\cdot\text{m}^{-3}$ (including tetrachloroveratrole (4CL-VER), pentachloroanisole (PCA), and dieldrin (DIELD)) and ~15 $\text{pg}\cdot\text{m}^{-3}$ (endosulfan). Hexachlorobenzene (HCB) was present at higher levels. These measurements were analysed with air parcel back trajectories and other meteorological information to provide insight into sources, transport, and chemical transformation of OC pesticides to the western Canadian Arctic. In winter, unusually high air concentrations of HCHs, DDT, and chlordanes at Tagish were predominantly influenced by trans-Pacific long-range atmospheric transport from eastern Asia that generally occurred within five days (Figure 2). HCH and heptachlor epoxide (HEPT EPOX) concentrations were correlated with the time that air spent over eastern Asia prior to arrival at Tagish (Figure 3). However, chlordane and DDT, which also increase with trans-Pacific transport, do not show a correlation with time the upwind airshed included Asia (Figure 3) as these pesticides can undergo partial degradation in soils prior to transport. Trans-Pacific transport from Asia did not result in exceptional levels of other OC pesticides such as dieldrin and endosulfan. Air masses originating predominantly from North America had the highest concentrations of HCHs, chlordanes, and endosulfan when the 5-day upwind airshed included the western United States. Endosulfan concentrations may also be influenced by suspected usage of endosulfan in the west coastal and prairie regions of Canada. When the occurrence of long-range transport from Asia was low, such as in the summer, most OC pesticides exhibited a significant dependence of atmospheric concentration on land surface temperature.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U. S. S. R.
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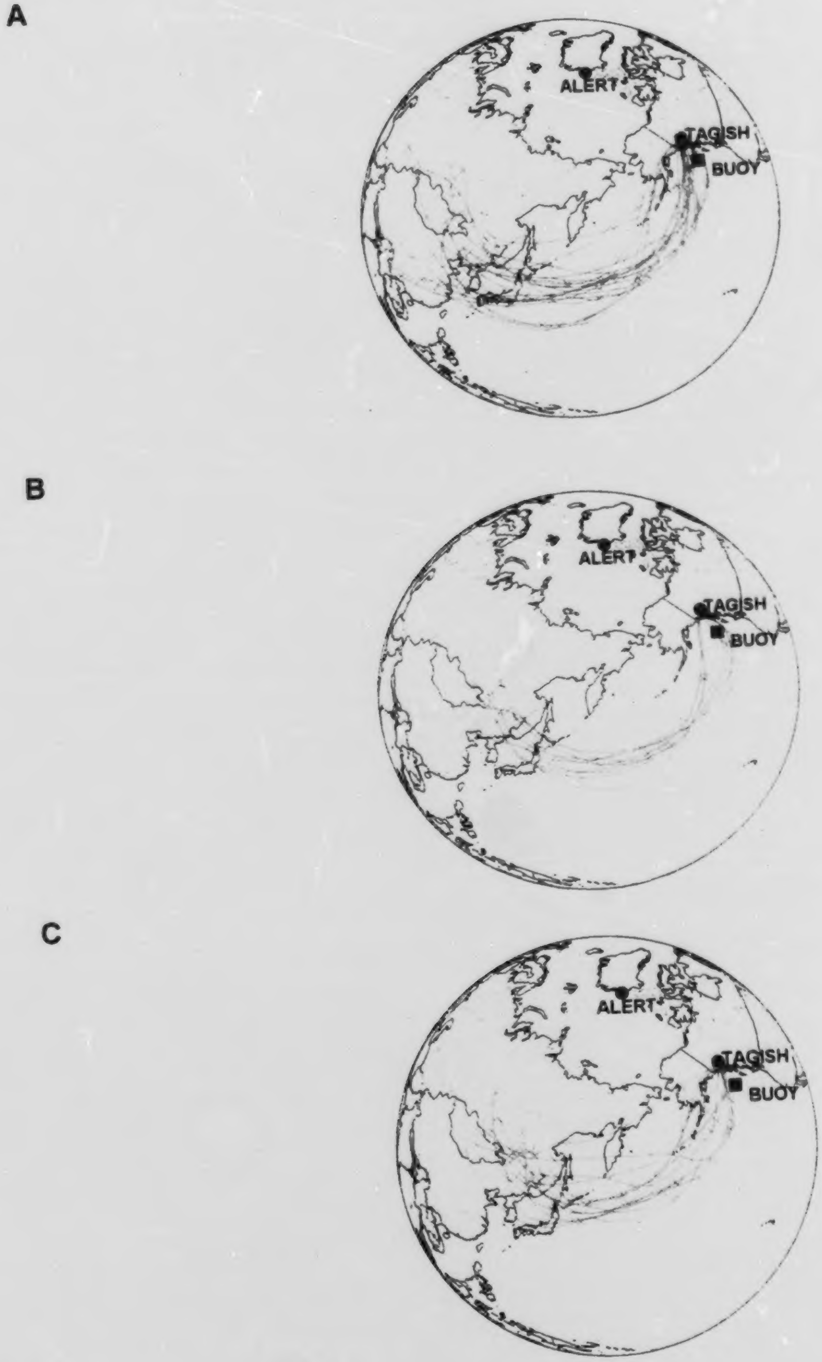
30°
15°
GREENLAND
L
ARCTIC CIRCLE
TAGISH
C.DORSET
ATLANTIC OCEAN
CANADA
U. S. A.
Transport of pollutants into the Arctic
Primary sources of air pollution
Major rivers flowing into Arctic Ocean
Surface ocean currents
Winter air circulation
H High-pressure cell (clockwise flow)
L Low-pressure cell (counterclockwise flow)
Prevailing winds

Figure 1. Locations of Northern Contaminants Program's air monitoring stations (black ovals). Ny Ålesund is operated by the Norwegians.


A
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C
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TAGISH
BUOY

Figure 2. Long-range atmospheric trajectories to Tagish arriving at 700 hPa level (~1500 m) during strong trans-Pacific transport out of Asia for three seasons: A. Winter (December to February); B. Spring (March-May); and C. Fall (September-November). Not shown is the summer season (June-August) as no trans-Pacific transport out of Asia occurred.

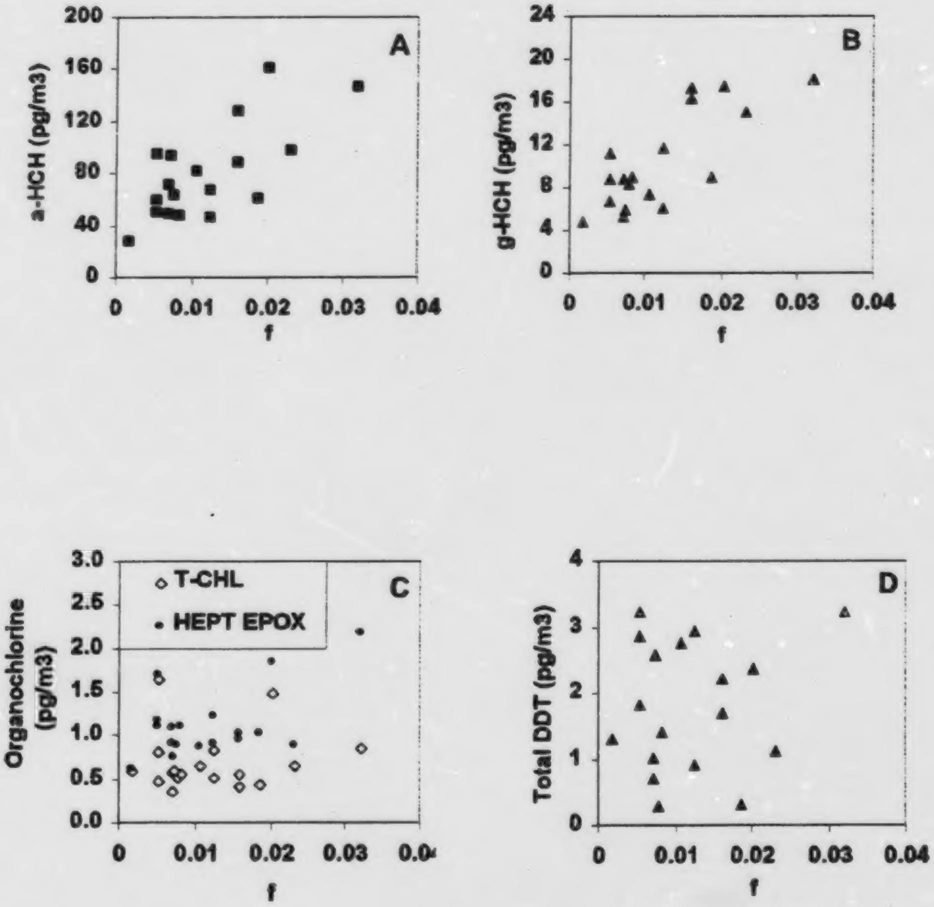

Figure 3. Dependence of (A) α-HCH, (B) γ-HCH, (C) heptachlor epoxide and trans-chlordane, and (D) total DDT concentration (gas + particle) on fraction of the time the 5-day upwind airshed included Asia (f) for sampling periods with strong trans-Pacific transport from Asia.

Table 1. A comparison of average and standard deviation (in brackets) of weekly atmospheric concentrations of OC pesticides in the gas and particulate phase in the Canadian Arctic at Tagish, Yukon and Alert, Nunavut in summer and winter.

	Tagish Winter		**Tagish Summer**		**Alert Winter**		**Alert Summer**	
(pg·m^{-3})	Particle	Gas	Particle	Gas	Particle	Gas	Particle	Gas
HCB	0.08(0.13)	42.4(11.6)	0.05(0.08)	27.2(14.9)	0.13(0.28)	58.8(47.7)	0.12(0.13)	45.4(17.6)
α-HCH	0.14(0.23)	64.8(28.5)	0.15(0.14)	61.3(23.4)	1.07(1.82)	66.8(51.4)	0.06(0.10)	55.0(43.9)
γ-HCH	0.07(0.09)	9.29(4.17)	0.04(0.05)	12.2(7.45)	0.87(1.65)	11.8(9.5)	0.02(0.05)	10.7(12.1)
OXYCHL	0.02(0.01)	0.72(0.31)	0.02(0.01)	0.89(0.23)	0.10(0.17)	0.77(0.64)	0.02(0.01)	1.27(0.56)
C-CHL	0.02(0.02)	1.02(0.49)	0.01(0.00)	1.11(0.41)	0.24(0.46)	0.97(0.73)	0.01(0.01)	1.44(0.78)
T-CHL	0.01(0.01)	0.61(0.31)	0.01(0.00)	0.38(0.15)	0.14(0.23)	0.52(0.47)	0.01(0.00)	0.55(0.36)
C-NONA	0.01(0.01)	0.08(0.09)	0.01(0.00)	0.11(0.10)	0.02(0.03)	0.04(0.05)	0.01(0.01)	0.24(0.12)
T-NONA	0.01 (0.01)	0.78(0.45)	0.09(0.35)	1.00(0.50)	0.16(0.28)	0.63(0.56)	0.01(0.01)	1.47(0.87)
HEPTCHL	0.01(0.01)	0.02(0.01)	0.01(0.00)	0.02(0.01)	0.01(0.01)	0.02(0.02)	0.01(0.00)	0.02(0.01)
HEPT EPOX	0.01(0.01)	0.88(0.47)	0.01(0.01)	1.43(0.41)	0.17(0.33)	0.82(0.76)	0.01(0.01)	1.60(0.78)
p,p'-DDT	0.02(0.01)	0.12(0.13)	0.02(0.01)	0.12(0.13)	0.05(0.07)	0.11(0.13)	0.02(0.01)	0.16(0.14)
o,p'-DDT	0.02(0.01)	0.36(0.35)	0.02(0.01)	0.53(0.30)	0.05(0.07)	0.21(0.28)	0.02(0.01)	0.41(0.39)
p,p'-DDE	0.02(0.01)	0.45(0.37)	0.01(0.00)	0.23(0.13)	0.11(0.25)	0.51(0.64)	0.01(0.00)	0.23(0.21)
o,p'-DDE	0.02(0.01)	0.13(0.13)	0.02(0.01)	0.12(0.12)	0.02(0.02)	0.17(0.24)	0.02(0.01)	0.14(0.18)
ENDO	0.04(0.06)	5.50(2.92)	0.05(0.11)	7.38(1.93)	0.18(0.30)	3.42(3.32)	0.02(0.01)	5.79(3.65)
DIELD	0.03(0.04)	0.76(0.54)	0.03(0.05)	0.87(0.27)	0.31(0.42)	0.74(0.72)	0.02(0.05)	1.67(0.82)
4CL-VER	0.07(0.04)	2.07(1.43)	0.07(0.03)	0.90(1.75)	0.08(0.06)	1.20(1.52)	0.07(0.03)	1.03(2.05)
PCA	0.02(0.01)	3.03(1.06)	0.02(0.03)	1.80(0.81)	0.02(0.03)	4.12(3.41)	0.01(0.01)	1.89(0.77)

Winter: October 1993-April 1994

Summer: May 1994 - September 1994

HCB, hexachlorobenzene, α- and γ-HCH, hexachlorocyclohexane isomers; OXYCHL, oxychlordane; C-CHL, *cis*-chlordane; T-CHL, *trans*-chlordane; C-NONA, *cis*-nonachlor; T-NONA, *trans*-nonachlor; HEPTCHL, heptachlor; HEPT EPOX, heptachlor epoxide; *p,p'*-DDT and *o,p'*-DDT, isomers of dichlorodiphenyltrichloroethane; *p,p'*-DDE and *o,p'*-DDE, isomers of dichlorodiphenyldichloroethene; ENDO, endosulfan; DIELD, dieldrin; 4CL-VER, tetrachloroveratrole; and PCA, pentachloroanisole

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Bailey, R., L.A. Barrie, C.J. Halsall, P. Fellin and D.C.G. Muir. 1999. Atmospheric organochlorine pesticides in the western Canadian Arctic: Evidence of trans-Pacific transport (submitted to Journal of Geophysical Research).

NEW PERSISTENT CHEMICALS IN THE ARCTIC ENVIRONMENT

Project Leaders: Terry F. Bidleman, Atmospheric Environment Service (AES), Downsview, ON;
Derek C.G. Muir, National Water Research Institute (NWRI), Burlington, ON;
Gary A. Stern, Freshwater Institute (FWI), Winnipeg, MB

Project Team: Tom Harner, Paul Helm and Len Barrie, AES; William Strachan, Mehran Alaee, Michael Comba and Sean Backus, NWRI; Greg Tomy, FWI; Mike Ikonomou, Institute of Ocean Sciences (IOS); Phil Fellin, Conor Pacific; Frank Wania, Wania Environmental Chemists Corp.

OBJECTIVES

1. To determine coplanar polychlorinated biphenyls (PCBs), polychlorinated naphthalenes (PCNs), brominated and chlorinated diphenyl ethers (BDPEs/CDPEs) and chloroparaffins in air from Arctic monitoring stations and in marine mammals.
2. To search for other "new" chemicals in the Arctic environment, not currently monitored by the Northern Contaminants Program (NCP), but of potential concern based on known persistence, extent of usage and toxicology.

DESCRIPTION

This project focusses on "new" chemicals in the Arctic environment – new because they are not being currently monitored by the NCP or new in the sense of being currently used in Canada, the U.S. and Europe (e.g. pesticides). From a national and international regulatory perspective, finding new chemicals in the Arctic implies that these compounds are sufficiently persistent in the atmosphere and sea water to be transported long distances from sources. Both the Canadian Toxic Substances Management Policy and the United Nations Economic Commission for Europe (UN-ECE) draft protocols on persistent organic pollutants (POPs) include the presence of chemicals in remote environments as evidence of persistence. If found in Arctic food webs, there is the added threat that these compounds are bioaccumulative and are contaminants of human food. Other monitoring programs such as the Integrated Atmospheric Deposition Network (IADN) in the Great Lakes are also interested in the long-range transport of current-use pesticides and other halogenated aromatic compounds.

Pesticides

A study by Chernyak *et al.* (1996) reported the presence of the pesticides chlorpyrifos, atrazine, endosulphan, chlorothalonil, metolachlor and trifluralin in seawater or fog water samples in the Bering Sea. Endosulphan has been frequently measured in Arctic air (Halsall *et al.* 1998, Bidleman *et al.* 1995) and surface seawater (Jantunen and Bidleman 1998). Pentachloroanisole (PCA), a metabolite of the wood preservative pentachlorophenol (PCP) is also routinely found in air at Arctic air monitoring stations (Halsall *et al.* 1998), and free PCP has been measured in Yellowknife (Waite *et al.* 1998). All of these pesticides are currently used in Canada, the U.S. and Europe. Barrie *et al.* (1997) noted that the degradation rates of pesticides which are regarded as relatively non-persistent in temperate environments, are much slower in the Arctic.

Organochlorine pesticides are already being monitored by the NCP, but pesticide enantiomers and photoisomers are not included. Examining these could enhance our understanding of transport, sources and delivery to the food chain. The enantiomeric composition of chiral pesticides provides clues to their sources. For example, *trans*- chlordane in ambient air over the Great Lakes is non-racemic, indicating that it is not from current usage but "recycled" by volatilization from contaminated soils or the lake itself (Bidleman and Falconer 1999). The finding of non-racemic heptachlor epoxide in air over the Great Lakes is also evidence of emission from soils (Bidleman *et al.* 1998). The enantiomers of α-HCH (hexachlorocyclohexane) allow volatilization from the Arctic Ocean to be differentiated from long-range transport (Jantunen and Bidleman 1996).

Halsall *et al.* (1998) found that the proportion of *trans-/ cis*-chlordane at Arctic air monitoring stations has decreased in recent years, suggesting an "older" source of chlordane. This could indicate that the chlordane we are now seeing in Arctic air comes from re-emission rather than current usage. Recently it has been shown that at least one chlorobornane congener is non-racemic in Melipax, a toxaphene-like product from the former German Democratic Republic (Vetter and Schurig 1997). Also, it is possible that enantioselective degradation of chlorobornanes takes place in soils. Measuring the enantiomer ratios for these pesticides can yield information on sources and pathways.

Enantiomers are also valuable indicators of selective metabolism and bioaccumulation processes. Large differences in accumulation properties for the individual enantiomers of α-HCH, chlordane compounds, heptachlor epoxide and methylsulphonyl PCBs have been found in the food chain arctic cod - ringed seal - polar bear (Wiberg *et al.* 1998). Several components of toxaphene are chiral, including the hexa- and hepta-chlorobornanes that are produced by diagenesis in sediment. Examining the enantiomeric composition of these would provide clues to their mechanism of formation (e.g. abiotic vs. microbial dechlorination) and bioaccumulation.

Photoheptachlor, a persistent, bioaccumulative and toxic transformation product of heptachlor, has been identified in ringed seal blubber, polar bear fat and human plasma from Northern Quebec (Zhu *et al.* 1995), but is not included in the list of pesticides monitored in air and water. Jakalski and Khan (1993) found that aldrin and dieldrin in phytoplankton were converted to their more toxic photoproducts, indicating the potential of phytoplankton to alter the chemical and biological characteristics of hazardous chemicals present in surface waters.

Industrial Chemicals

Reviews of data on contaminants in Arctic food webs found that information was limited or non-existent on levels of certain industrial compounds: PCNs, chlorinated and brominated diphenyl ethers (CDPEs, BDPEs) and chloroparaffins (de Marche *et al.* 1998, Muir *et al.* 1997). These contaminants have been detected in biota in Svalbard and in northern and southern Sweden (Falandysz and Rappe 1996, Jansson *et al.* 1993, Järnberg *et al.* 1993, 1997, Sellström *et al.* 1993). PCNs have also been found in human adipose tissue from Ontario municipalities (Williams *et al.* 1993), demonstrating their ability to be transferred to people.

Prior to this study, neither PCNs nor coplanar PCBs had been measured in air samples from the Canadian Arctic. Several PCNs exhibit dioxin-like activity and have been assigned toxic equivalency factors. Järnberg *et al.* (1993) found that 12% of the TEQ in pike from Lake Vänern, Sweden was contributed by 1,2,3,4,6,7- and 1,2,3,5,6,7-hexachloronaphthalene. Coplanar and mono-ortho PCBs were found in fish from the Slave River (McCarthy *et al.* 1997), caribou (Hebert *et al.* 1996) and Arctic marine mammals (Norstrom and Muir 1994). The coplanars accounted for 14% of the dioxin-type toxic equivalents (TEQ) in human plasma samples from Northern Quebec, and 64% of the TEQ was contributed by mono- and di-ortho PCBs (Ayotte *et al.* 1997).

Of the chloroparaffins, the short-chain C_{10}–C_{13} compounds (SCCPs) have the greatest potential for environmental release (Environment Canada 1993) and exhibit the highest toxicity (Willis *et al.* 1994). Researchers in Sweden have found that the SCCPs inhibit intercellular communication in rat liver epithelial cells, a phenomenon which suggests that these chemicals may be acting as tumour promotors (Kato and Kenne 1996). In Canada, short-chain PCAs are classified as priority toxic substances.

BDPEs are flame retardant chemicals that are added to manufactured products including paints, plastics, and textiles (van Esch 1994); as such they can be released into the environment when the products containing BDPEs are discarded (Hutzinger *et al.* 1976, Hutzinger and Thoma 1987) . The annual production of BDPE in 1992 was 40,000 tons, and it continues to grow consistently (van Esch 1994). The extensive use of products containing BPDEs has resulted in the release of these compounds into the environment. BDPEs are lipophilic compounds and are shown to bio-accumulate through the food web (Sellström *et al.* 1993).

BDE-209 (deca-BDE) was detected in soil and sludge in the areas surrounding plants where BDPEs were manufactured in the U.S. (De Carlo, 1979). Two years later Andersson and Blomkvist (1981) reported the presence of BDPEs in samples collected along Visken River in Sweden. Jansson *et al.* (1987) first indicated that BDPEs are global contaminants by demonstrating the presence of BDPEs in fish-eating birds and marine mammals in samples collected from the Baltic Sea, North Sea and Arctic Ocean. BDPE congeners were observed in marine fish, shellfish, and sediment (Watanabe *et al.* 1987) and in air particulate matter from Japan and Taiwan (Watanabe *et al.* 1992). BDPEs were also reported in cod liver and herring from the North Sea (de Boer 1989), and in eels from freshwater systems in the Netherlands (de Boer 1990). Stafford (1983) reported the presence of BDPEs in eggs and tissues of fish-eating birds from six states in the US and from Ontario, Canada. Stanley *et al.* (1991) reported the presence of BDPEs in human adipose tissue. Norén and Meironyté (1998) found that BDPEs in human milk increased over the past 25 years and that concentrations of BDPEs doubled every five years.

CDPEs are a group of potentially significant organochlorine contaminants. CDPEs can be formed as by-products in the manufacturing process of chlorophenols (Firestone *et al.* 1972) or in combustion processes (Paasivirta *et al.* 1986). Individual CDPE congeners have been reported to be immunotoxic and induce hepatic microsomal enzymes (Howie *et al.* 1990). Toxicity and induction depends on structure, but relationships are not similar to PCBs. The mono-*ortho* chloro-substituted CDPE congeners have been shown to be more potent inducers of aryl hydrocarbon hydroxylase (AHH) and ethoxyresorufin-O-deethylase (EROD) activities and more immunotoxic than their non-*ortho* analogues

(Howie *et al.* 1990), whereas the non-*ortho* PCBs are more active than the mono-*ortho* PCBs. Relative toxicities, toxic equivalent factors (TEFs), for the non- and mono-*ortho* CDPEs according to Safe (1992) are similar to the mono-*ortho* substituted PCBs (TEF_{CDPEs} = 0.001). CDPEs are known to be persistent in the environment and can act as precursors of polychlorinated dibenzo-*p*-dioxin (PCDD) and polychlorinated dibenzofurans (PCDFs) in photolytic reactions (Humppi and Keinola 1985). As with BDPEs, CDPEs have been detected at $\mu g \cdot kg^{-1}$ levels (lipid weight) in fish, fish-eating birds and marine mammals from remote areas (Paasivirta *et al.* 1986, Koistinen *et al.* 1993, 1995), but extremely limited information is available in Arctic marine mammals. Koistinen *et al.* (1993) reported a mean ΣCDPE concentration of 7.89 $ng \cdot g^{-1}$ (lipid weight) in salmon muscle from the Tenojoki River, Finland.

Haloacetic Acids

In addition to the above new chemicals, it is likely that haloacetic acids (HAAs) are present in the Arctic environment. HAAs can be classified as persistent but non-accumulating chemicals. However, HAAs are phytotoxic and trichloroacetic acid (TCA) has been used as a herbicide. Environmental emissions of trifluoroacetic acid (TFA) are expected to increase because it has been found to be an atmospheric degradation product of several hydrofluorocarbons and hydrochlorofluorocarbons (HCFCs) which are being introduced as replacements for the ozone-destroying chlorofluorocarbons (CFCs) under the Montreal Protocol. The Henry's Law constants of HAAs are low (<0.1 $Pa\ m^3 \cdot mol^{-1}$) and characteristic of chemicals that are efficiently removed from the atmosphere by precipitation and air-water gas exchange, making them likely candidates for contamination of Arctic snow and water.

ACTIVITIES IN 1998/99

Sample Acquisition

Participating laboratories have worked to develop the capability for analysing a wider range of POPs and current-use pesticides with application to air, marine mammals and seawater. The chemicals include PCNs, coplanar PCBs and pesticide enantiomers, currently used pesticides, BDPEs and CDPEs, chlorophenols (including PCP) and SCCPs. The following samples were acquired and analytical methods are briefly outlined below.

Air Samples

Monthly air samples (combined extracts of weekly samples) from Alert and Dunai for 1994 were received from the archives. These were equally split among the three participating laboratories.

Marine biota

Blubber samples from five Pangnirtung beluga were analysed for BDPEs and CDPEs by the Department of Fisheries and Oceans (DFO) Freshwater Institute laboratory in Winnipeg. For a study of new pesticides, we compiled results of previous work carried out at the Freshwater Institute, on plankton, Arctic cod and beluga muktuk, for which ΣPCB and ΣHCH have been previously reported (e.g. Muir 1997). The National Water Research Institute (NWRI) laboratory also analysed 44 samples of ringed seal blubber collected in 1998 from two locations in Labrador and three locations in the Ungava Bay/Hudson Strait region of Northern Quebec.

Seawater

Sea water samples were collected during several cruises in the Canadian Arctic as part of the Surface Heat Budget of the Arctic Ocean (SHEBA) and the Northwater Polynya (NOW) programs. The samples from Baffin Bay and Kane Basin were collected by A. Fisk (Canadian Wildlife Service) as part of the NOW studies. Those from SHEBA were collected by Rob Macdonald (DFO, IOS) and colleagues. Three large volume seawater samples (100 L) from the Canadian Archipelago were collected by W. Strachan (NWRI) during the September 1997 Joint Ocean Ice Study (JOIS) cruise and sub-sampled for HAAs. Samples were collected in 1 L polypropylene bottles, refrigerated after collection and shipped in coolers at 4°C to NWRI Burlington.

Analysis

Methods for analysis of SCCPs were reported last year (Muir *et al.* 1999). Tomy *et al.* (1998) published the results of an international inter-laboratory study in which seven different laboratories compared their quantitative methods used for measuring SCCP. Samples quantified in this study consisted of "known" but unstated concentration of a commercially available SCCP product and a number of "real world" environmental samples.

CDPEs and BDPEs were determined in air and marine mammal samples by high resolution electron ionization mass spectrometry using the method described by Sergeant *et al.* (1998). Prior to GC-MS analysis the compounds were isolated by elution from 3% deactivated silica gel column with dichloromethane.

Custom standard solutions were purchased from Cambridge Isotope Laboratories (Andover, Massachusetts), and comprise analytical, surrogate spiking, and performance Standards. One hundred µL of extract was transferred into a GC vial and was spiked with the $^{13}C_{12}$-tetra- through octa-CDPE surrogate mixture. The sample was evaporated to dryness at room temperature to minimize losses and 20 µL performance standard (100 p·µL $^{13}C_{12}$ hexa-CDPE and tetra-BDPE) added for analysis.

High resolution GC/MS determination of BDPE and CDPE was carried out on a VG AutoSpec-Q mass spectrometer connected to a Hewlett-Packard 5890 GC equipped with a CTC A200s autosampler. The GC injection port was configured for 1 µL on-column injections, with an initial temperature of 110°C, held for one minute, ramped at 100°C per minute to 280°C and held there for 55 minutes. Gas chromatographic separation prior to MS was achieved using a 60m x 0.25 mm x 0.25mm Restek Rt$_x$5 capillary column. The GC conditions were the same as above except that the final hold was extended to 60 minutes. Total run time was 90.7 minutes. Sample ionization was performed by electron ionization (EI) at an electron voltage ranging from 30 to 40 eV depending on the optimal parameters of the instrument. Source temperature was 270°C and the resolving power of the analyser was 10 000. The mass spectrometer was operated in SIM mode using a total of eight descriptors to analyse the 23 BDPE congeners. Quantitation of samples was by internal standard method with a 20/20 spreadsheet, using EPA 8290 QA/QC protocols.

PCNs and coplanar PCBs were determined in air by GC - negative ion mass spectrometry using Hewlett-Packard MS Engine with methane reagent gas. A 30m DB-5 column was used for the analysis. The air samples were first fractionated on alumina-silica columns to separate PCBs and PCNs from organochlorine (OC) pesticides. Fraction 1 (eluted with petroleum ether) was subjected to further fractionation on mini-columns of silica and activated carbon to separate multi-*ortho* PCBs (eluted with cyclohexane - dichloromethane) from PCNs and coplanar PCBs (eluted with toluene). PCNs were quantified against Halowax 1014, a commercial PCN mixture. The percentages of individual congeners in Halowax 1014 were determined by GC - flame ionization detection, and this mixture was then used as the standard for PCN determinations. Single-congener standards were used for the coplanar and mono-*ortho* PCBs with ^{13}C-labelled congeners of PCBs 77, 105, 126 and 169 as recovery surrogates and either PCB-103 or mirex as an internal standard. Methods have been published by Harner and Bidleman 1997 and Harner *et al.* (1998).

In previous work at DFO Winnipeg, endosulphan isomers in plankton, Arctic cod and muktuk were determined by GC-ECD using 60 m x 0.25 mm i.d. DB-5 columns with H$_2$ carrier gas. Confirmation was by exact retention time matching with authentic standards. For the ringed seal blubber, which was analysed by the NWRI laboratory, endosulphan isomers were determined on a 30m x 0.25m DB-5 column using pressure programming and confirmed with a DB-1 column. Samples were also analysed for other current use pesticides such as lindane (γ-HCH) and pentachloroanisole (PCA, a methylation product of pentachlorophenol), as well as PCBs. Only PCA was determined and not the parent compound pentachlorophenol. Reagent blanks were also analysed for endosulphan isomers and the sulphate in both laboratories.

Samples for HAAs were analysed using the method of Scott and Alaee (1998) with minor modifications. In brief, seawater samples were evapo-concentrated (50 mL) and HAAs were derivatized *in situ* with 2-fluoroaniline in the presence of the dicyclohexylcarboiimide to yield fluoroanilides HAAs. The fluoroanilides were analysed by selected ion monitoring GC-MS (Scott and Alaee 1998).

RESULTS AND DISCUSSION

Air Samples

A pilot study of new chemicals in Arctic air was carried out with mid-year funding received in October 1997. The samples from Alert-Dunai consisted of six polyurethane foam (PUF) and three glass fiber filter (GFF) extracts, representing spring, summer and winter months of 1994, plus a blank PUF and GFF. Samples from the 1996 Oden expedition of the eastern Arctic Ocean were also analysed. Results of this initial study for PCNs, coplanar PCBs, SCCPs and BDPEs were reported to NCP last year (Bidleman *et al.* 1999, Muir *et al.* 1999).

The above measurements of PCNs and coplanar PCBs have recently been published (Harner *et al.* 1998). Work is being done to improve analytical methods for PCNs with the goal of increasing the number of PCN congeners that can be separated. Special attention is being given to resolving PCNs that have dioxin-like activity or are characteristic of different source types (e.g. Halowax fluids vs. combustion-derived).

The archived air samples received during 1998/99 have been analysed for BDPEs. Results from the mid-year study, summarized in Figure 1, indicated that the majority of the BDPEs are collected on the front polyurethane foam plug (P1). These results are consistent with other organohalogen compounds. BDPE levels observed in Alert were higher than Dunai. This can be attributed to the higher usage of these compounds in North America than in Russia. The peak concentration of BDPEs were July and August, indicating more volatilization from the southern regions. The majority of PBDEs observed in this study contained tetra bromo followed by the penta bromo homologue group. Over 80% of the tetra homologue group was BDE 47 (2,2',4,4'-tetra BDE) and BDE-99 (2,2',4,4',5-penta BDE). These results are consistent with those observed in marine mammals from the Arctic, and lake trout from the Great Lakes.

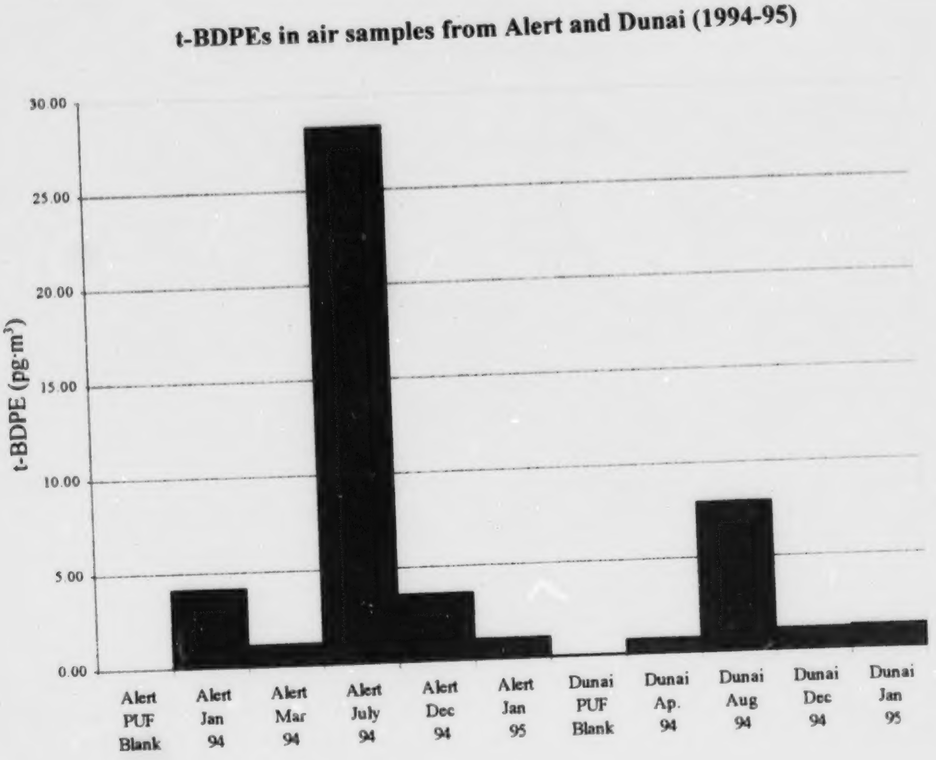

Figure 1. t-BDPEs in air samples from Alert and Dunai (1994–95).

Biota Samples

Five Pangnirtung beluga were analysed for CDPEs and BDPEs in the study of temporal trends of contaminants in marine mammals, and as part of the new chemicals project. The work was done by G. Stern (FWI) and M. Ikonomou (IOS). Results (Tables 1 and 2) are presented here and also in this year's report on the temporal trends project (Stern and Addison 1999). Mean concentrations of BDPE and CDPE in the Pangnirtung beluga were 10.24 ±2.30 and 60.44 ±9.12 $ng \cdot g^{-1}$, respectively. As observed in blubber samples from Kimmirut beluga (Muir *et al.* 1999), the Br4-DPEs were predominant, in particular the 2,2',4,4'-BDPE congener which represents ~80% of the total. Four-fold higher BDPE levels were observed in the Pangnirtung beluga, but this can almost certainly be attributed to the fact that the mean age of the Pangnirtung animals was 20.2 years relative to 6.3 years for the Kimmirut animals. BDPE concentrations were about six-fold lower than CDPE concentrations which, in turn, were about 80-fold lower than PCBs.

A paper on an interlaboratory study of analytical methods for chloroparaffins has been published (Tomy *et al.* 1998) and a new medium chain (C_{14}-C_{17}) chloroparaffin methods paper has recently been accepted for publication (Tomy and Stern 1999).

Endosulphan is widely used in the U.S. and Canada for insect control on high value crops. Major use areas are in the corn belt of the U.S. (U.S. Geological Survey 1998) and southwestern Ontario. Approximately 900 tonnes were used annually in the mid-1990s in the U.S., mainly on cotton and fruit crops. Endosulphan (alpha and beta isomers) and its oxidative degradation product endosulphan sulphate have previously been determined in Arctic air and confirmed by high resolution GC-MS (Halsall *et al.* 1998). There are no previous reports for endosulphan in the Arctic marine food web.

Endosulphan (α– and β– isomers) and endosulphan sulphate were detectable in plankton and Arctic cod at low $ng \cdot g^{-1}$ levels (Table 3). Endosulphan sulphate was the most prominent form of endosulphan in all samples. Levels of lindane, PCA and ΣPCBs are reported for comparison. The sulphate was present at similar levels to lindane in plankton and muktuk. Highest endosulphan levels were found in beluga muktuk, which was primarily skin (average lipid content = 19%) and in ringed seal blubber.

Ringed seal blubber contained higher levels of β-endosulphan than the α-isomer. Endosulphan sulphate was not determined in the seal blubber. Reagent blanks

Table 1. Brominated diphenyl ethers ($ng \cdot g^{-1}$) in blubber samples from five male Pangnirtung beluga (age>17 years).

Sample	Year	Br_3-DPE	Br_4-DPE*	Br_5-DPE	Br_6-DPE	Br_7-DPE	ΣBDPE
B-92-06	1992	0.713	6.52	0.715	0.244	0.006	**8.20**
B-92-10	1992	0.807	8.96	1.04	0.410	-	**11.22**
B-92-13	1992	0.932	8.85	1.15	0.020	-	**10.95**
B-95-59	1996	0.663	5.41	0.628	0.027	0.130	**6.85**
B-95-544	1996	0.887	9.69	1.20	0.125	0.046	**11.95**

*In each sample the 2,2',4,4'-BDPE congener corresponds to ~ 80% of Tetra-BDE

Table 2. Chlorinated diphenyl ethers (CDPEs) and PCB concentrations ($ng \cdot g^{-1}$) in blubber samples from four male Pangnirtung beluga (age>17 years).

Sample	Year	Cl_3-DPE	Cl_4-DPE	Cl_5-DPE	Cl_6-DPE	Cl_7-DPE	Cl_8 -DPE	ΣCDPE	PCBs
B-92-06	1992	0.363	4.49	8.15	39.0	7.59	2.17	**61.76**	6596
B-92-10	1992	0.201	2.53	6.25	40.0	8.75	2.77	**60.50**	6037
B-92-13	1992	0.244	2.71	4.63	47.0	11.0	3.95	**69.53**	5981
B-95-544	1996	0.703	4.61	8.19	33.0	3.51	1.29	**51.30**	4965

Table 3. Concentration of current use pesticides: lindane, pentachlorophenol (as anisole) and endosulphan in Arctic marine biota ($ng \cdot g^{-1}$ wet weight).

Species/Location		N	Lipid %	γ-HCH	PCA	α-Endo	β-Endo	Endo Sulphate	ΣPCB
Plankton >150 um	mean	3	26	0.39	<0.01	0.11	0.08	0.63	54.5
W. Hudson Bay, 1995	SD		14	0.11	-	0.05	0.04	0.23	15.0
Arctic cod (whole)	mean	3	7	0.47	0.11	0.10	<0.01	0.30	6.2
Resolute Bay, 1993	SD		0.4	0.08	0.02	0.02	-	0.10	1.2
Beluga muktuk	mean	14	19	5.3	0.00	1.11	0.8	4.5	828
E. Hudson Bay, 1995	SD		9	2.1	0.00	0.47	0.2	2.5	306
Ringed seal blubber	mean	20	96	4.1	0.24	0.53	1.9		565
N. Quebec/Labrador - females - 1998	SD		14	1.5	0.17	0.35	1.2		306
Ringed seal blubber	mean	24	90	4.2	0.26	0.66	2.0		598
N. Quebec/Labrador - males - 1998	SD		10	2.8	0.18	0.71	2.4		369

Table 4. Average concentrations of trifluoroacetic acid ($ng \cdot L^{-1}$) in Arctic seawater (1998)*

Location	Samples (N)	Depth (m)	$ng \cdot L^{-1}$
Baffin Bay (E1)	7(x2)	489	141
Kane Basin (N1)	8(x2)	579	145
S. Baffin Bay (S5)	6(x2)	365	125
Beaufort Sea (75N 140W) SHEBA I	20	1500	122
Beaufort Sea (75N 160W)SHEBA II	15	3000	127

* Samples from Baffin Bay and Kane Basin were duplicates (x2). Those from SHEBA were mainly single replicates over a depth profile.

analysed with the ringed seal blubber contained trace levels of endosulphan equivalent to 0.05 ng·g^{-1} α-endosulphan and 0.1 ng·g^{-1} β-endosulphan, well below levels in environmental samples. Mean endosulphan levels in males and females did not differ significantly (t-test at $P<0.05$). α-endosulphan was strongly correlated with β-endosulphan in males ($r=0.85$)and females ($r=0.76$). α- and β-endosulphan were also strongly correlated with γ-HCH in male ringed seals ($r=0.7$-0.8) but not in females. Neither isomer was correlated with ΣPCB nor with age of the animals. On a lipid weight basis, α-endosulphan increased in concentration by about 3x between plankton and arctic cod, and 10x between plankton and beluga muktuk but showed <2x increase between plankton and ringed seal. The results suggest that endosulphan does biomagnify in the Arctic marine environment although additional measurements on plankton and cod would be useful to confirm this preliminary observation.

Haloacetic Acids in Arctic Seawater

Of the eight haloacetic acids determined (mono-, di-, trichloro, mono-, di-, trifluoro, mono-bromo, dibromo-) only TFA was present above detection limits (1-5 ng·L^{-1}). Blanks (ultrapure water) showed low levels of TFA (<10 ng·L^{-1}). Although there was some variation with depth and between duplicates, especially at the SHEBA sites, overall mean levels of TFA were relatively consistent at all locations (Table 4). TFA was found at all depths at the SHEBA sites including water at up to 3000m. TFA is an atmospheric degradation product of HCFCs which are replacing CFCs in air conditioning. It is weakly phytotoxic and highly resistent to degradation (Boutonnet *et al.* 1999). There are concerns that increased use of HCFCs will result in a buildup of TFA in the aquatic environment. These levels in the Arctic suggest that TFA has a natural source or other unknown anthropogenic sources in the marine environment because they could not be generated by the current emissions of HCFCs.

Other Progress

Liquid-phase vapour pressures of 17 PCN congeners were determined directly by a capillary GC method, and correlation with previously published GC retention indices allowed vapour pressures to be estimated for all 75 PCNs. Relationships of vapour pressure to the number of chlorines (homologue and LeBas molar volume) were established. Heats of vapourization followed the order: non-*ortho* PCBs>PCNs ~ mono-*ortho* PCBs>multi-*ortho* PCBs. PCNs and coplanar PCBs have a greater affinity for octanol than multi-*ortho* PCBs. This implies that PCNs should partition to aerosols to a greater extent than multi-*ortho* PCBs of the same volatility, a phenomenon already established for coplanar PCBs in urban air (Falconer *et al.* 1995, Harner *et al.* 1998). The PCN vapour pressure study was carried out under a contract to F. Wania and was recently published (Lei *et al.* 1999).

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MODELLING AND EVALUATION OF CONTAMINANT ACCUMULATION IN THE ARCTIC MARINE FOOD WEB

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Project Team: Barry Hargrave, Bedford Institute of Oceanography (BIO), Department of Fisheries and Oceans (DFO)

OBJECTIVES

1. **To develop a model or models describing the accumulation of persistent organic pollutants (POPs) in Arctic marine food webs.**
2. To use the model(s) for the evaluation of existing food web contaminants data and to relate contaminant levels in biota to other environmental media (i.e. water, sediment, air).
3. To provide a framework for the design and evaluation of future field studies (i.e. the Arctic Archipelago Project).

DESCRIPTION

Persistent, bioaccumulative contaminants such as PCBs, DDTs, toxaphene, chlordane and mercury pose the greatest concerns for human and ecosystem health in the Arctic. The primary source of these contaminants to Northern peoples is from the consumption of marine mammals such as beluga (*Delphinapterus leucas*), narwhal (*Monodon monocerus*), ringed seal (*Phoca hispida*) and walrus (*Odobenus rosmarus*). The high contaminant levels found in marine mammals result from bioaccumulation processes through the marine food web in which marine mammals are at, or near the top of the web. Previous work resulted in the development of models describing the processes and rates of contaminant accumulation of persistent organic pollutants (POPs) by marine mammals for both individuals and populations, particularly for beluga and ringed seals (Hickie *et al.* 1999a, 1999b, Kingsley and Hickie 1993).

This report provides a summary of progress made on developing and assessing a model to predict the bioaccumulation of POPs throughout the Arctic marine food web. The project is being done in collaboration with Barry Hargrave (DFO-BIO) who is providing data from the 1993 POLARPRO year-round study near Resolute, NWT. The initial food web bioaccumulation model is based upon the existing pseudo steady-state model by Campfens and Mackay (1997). In this model, a food web is treated as a set of organisms with each having defined feeding preferences and physiological properties (e.g. size, growth rate, metabolic rate, lipid content). Bioaccumulation processes included are: exchange with water through the gills; uptake from food with a specified efficiency; and losses by egestion, metabolism and growth. Accumulation from sediment may also be considered for benthic organisms. The physical/chemical properties of contaminants are also considered as they affect both bioavailability and transfer efficiencies. A complete and detailed mass balance is included in the output of these models. Owing to the existence of the species-specific contaminants models for marine mammals, the primary goal of the food web model is to develop a quantitative/predictive link between contaminant concentrations in the environment (water and sediment) and the concentrations in organisms consumed by marine mammals or by Northern people directly.

ACTIVITIES IN 1998/99

Work during the past year has focussed on the following tasks:

Additional species

The species considered in the initial model were primarily those included in the POLARPRO contaminant study. These included: pelagic phytoplankton, two size classes of herbivorous zooplankton, the herbivore *Mysis oculata*, predaceous invertebrates *Themisto* and chaetognaths (e.g. *Parasagitta* sp.), and two age classes of Arctic cod. The model was extended this year to include several other species including Arctic char (*Salvelinus alpinus*), scavenger amphipods (e.g. *Anonyx nugax*), clams (*Mya truncata*), sculpins (*Myoxocephalus quadricornis*), and small benthic infauna. Char are an important country food for Northern people, while clams are the primary prey for walrus (*Odobenus rosmarus*). *Anonyx* and sculpins have both been considered as potential monitoring species for contaminants in the Arctic marine ecosystem. The addition of benthic species extends the model to include consideration of sediments as a potential source of contaminants to the food web. Contaminant data are available for *Anonyx* from the POLARPRO study, while data are available from the literature for Arctic char and, to a lesser extent, for clams and sculpins (Jensen *et al.* 1997).

Revision of the model bioenergetics subroutine

The respiration and feeding rates, or "bioenergetics", of organisms are critically important components in modelling contaminant bioaccumulation. Organism bioenergetics is a controlling factor for the rates of chemical uptake and loss across respiratory surfaces (gills) and the feeding rate which determines chemical exposure via the diet. The Campfens/Mackay food web model, like other current food web models, estimates the respiration rate of each organism as a function of body size using an allometric equation derived for aquatic organisms from temperate ecosystems. This allometric equation was revised to suit Arctic aquatic/marine organisms based on analysis of respiration rates collected from the literature for a variety of species ranging from zooplankton (Conover and Gustaveson 1999) to Arctic cod (Hop 1997) and Arctic char (Holeton 1973, 1974). Similar analyses were done to estimate the feeding rates of Arctic species and were incorporated into the model.

Stable Isotope Modelling

Ratios of nitrogen and carbon stable isotopes are used extensively to quantitatively estimate the trophic positions and feeding interactions of species in food web ecology and studies of contaminant bioaccumulation (Kidd *et al.* 1995). In contaminant studies, empirical relationships can be derived between contaminant concentrations in the organisms and their numerical trophic level scores which provide an overall measure of contaminant transfer efficiency between trophic levels (an average biomagnification factor). A subroutine was added to the model which predicts stable isotope-derived trophic level scores for each organism in the model food web based on its defined feeding preferences. The subroutine was based on a study of trophic relations in the marine food web of Barrow Strait-Lancaster Sound by Hobson and Welch (1992) where they developed the relationship

$$TL = 1 + (D_m - 5.4)/3.8$$

where TL is the trophic level of a consumer and D_m is the δ^{15}N value of the consumer's tissue. This novel model component provides a check that feeding preferences defined for each organism in the model are consistent with their trophic positions determined by measured δ^{15}N values. Calculated TL values were in good agreement with measured values as shown by the regression

$$TL_{calc.} = 0.97\ TL_{meas.} + 0.05\ (r^2 = 0.94, n=13).$$

Evaluation of model performance

Evaluation of the revised model was limited to six chemicals or groups of chemicals: ΣPCB, ΣDDT, ΣChlordane, HCB, α–HCH and γ–HCH. Model results for α–HCH and γ–HCH were combined to enable comparisons with data presented as ΣHCH. Model results were compared with average concentrations from the POLARPRO contaminant data set and data for other species compiled from the literature. Data for clams and mussels were from Cameron and Weiss (1993) and Muir *et al.* (1995); data for sculpins were from Bright *et al.* (1995); and data for anadromous Arctic char were summarized from Muir and Lockhart (1993). Sediment data were not available for the Barrow Strait-Lancaster Sound region, but were conservatively estimated based on sediment:water fugacity ratios of 1.0 for HCHs, 1.5 for HCB and 2.0 for ΣPCB, ΣDDT and ΣCHL.

Fugacity calculations for air, water and zooplankton

Fugacities were calculated for five organic chemicals (α–HCH, γ–HCH, HCB, *cis*-chlordane, and *trans*-chlordane) in Arctic air, sea water and zooplankton using data that were collected on a monthly basis as part of the POLARPRO study. Fugacity ratios were then calculated for water:air, zooplankton:air, and zooplankton:water (W:A, Z:A and Z:W, respectively). The W:A fugacity ratios for these chemicals were published previously by Hargrave *et al.* (1997), where they were used to estimate seasonal changes in chemical fluxes between sea water and air. Air concentration data used in these calculations were from the sampling station at Alert, NWT. Fugacity ratios between zooplankton, water and air were calculated to test the widely held assumption that concentrations of POPs in plankton are at, or near, equilibrium with their dissolved concentrations in water (i.e. at equal fugacity). This assumption is employed in most food web bioaccumulation models, including the Campfens/Mackay model. A Z:W fugacity ratio equal to one would validate this assumption. It would also demonstrate that chemical concentrations (or fugacities) in zooplankton could be used as a surrogate for water concentrations in estimating chemical fluxes between water and air. This would be especially useful for chemicals with extremely low water concentrations such as specific PCB congeners or DDT components. Deviations from unity would raise fundamental questions regarding our understanding of contaminant bioaccumulation at the lower trophic levels.

RESULTS AND DISCUSSION

Food Web Modelling

The relationship between observed concentrations ($ng \cdot g^{-1}$ lipid) and model-predicted concentrations for the 13 organisms considered in the food web model are

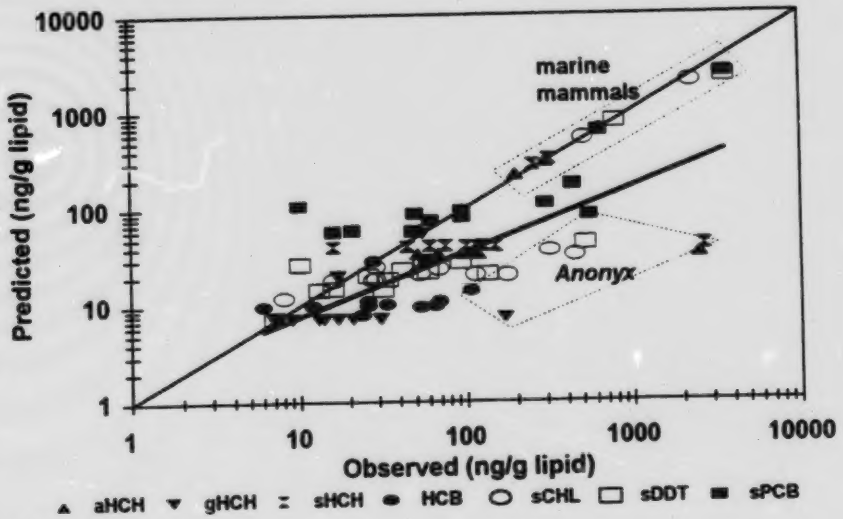

Figure 1. Model-predicted and observed concentrations of the six test chemicals in the organisms considered in the food web model. The regression line described in the text is shown in relation to the ideal 1:1 relationship.

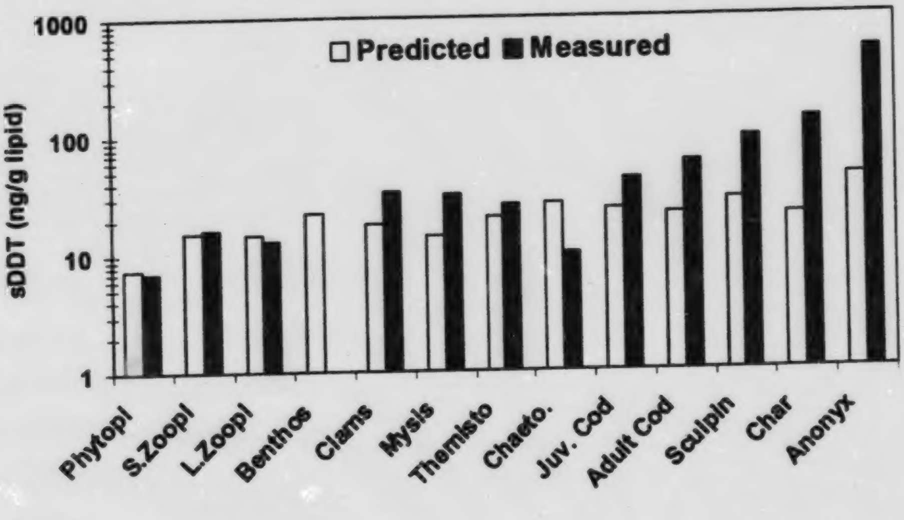

Figure 2. Observed and predicted concentrations of ΣDDT (ng·g^{-1} lipid) in organisms considered in the Arctic marine food web model.

shown in Figure 1. Results for ΣDDT are shown in greater detail in Figure 2. The only changes in model variables between trials for the six chemicals were to the chemical characteristics (molecular weight, log K_{ow}, Henry's Constant) and their concentrations in water and sediment. All other parameters were default values incorporated into the model data tables. Chemical concentrations in the blubber of male ringed seals and beluga whales (Muir *et al.* 1993) are included to provide an overall impression of the bioaccumulation of these chemicals through the entire marine food web. They are shown in relation to concentrations predicted using the models developed previously for beluga whales and ringed seals.

Overall, there was reasonable agreement between observed values and those predicted by the food web model as shown by the spread of data about the line denoting the ideal 1:1 relationship in Figure 1. About one-third of the predicted values fell within a factor of two of the measured concentrations, while about two-thirds fell within a factor of three. This level of resolution is similar to that reported for the Campfens/Mackay model (1997) when applied to the Lake Ontario food web. There was, however, a tendency to underestimate the extent of bioaccumulation through the food web from plankton to fish as shown by the linear regression

$$\log_{10}(C_{predicted}) = 0.67 \log_{10}(C_{observed}) + 0.32 \; (r^2 = 0.54,\ n = 90)$$

The model predicted a lipid-normalized biomagnification factor (BMF) of 1.0 (i.e. no biomagnification) for ΣHCH between plankton and fish (Arctic cod, char). BMFs calculated from measured concentrations were less that 1.0, which could result from some biotransformation of HCHs by fish. A modest degree of biomagnification was predicted for HCB (BMF = 1.4), but was less than the measured BMF value of 2.5.

Predicted plankton-cod and plankton-char BMFs for the remaining chemicals ranged from 2.0 for Σchlordane to 3.0 for ΣDDT and ΣPCB. These values were lower than the measured BMFs in all cases where values ranged from 2.3 for Σchlordane in arctic cod to 9.0 for ΣPCBs in char. Some of the discrepancies may result from underestimating the contribution of benthic contaminant sources to the food web. Combining data from a number of different locations and sources may also contribute to some of the differences.

At the base of the food web, predicted concentrations of HCHs, HCB and Σchlordane in zooplankton were lower than mean measured concentrations by factors of two to three, while concentrations were accurately predicted for ΣDDT or slightly overestimated for ΣPCB. These findings are of possible significance for several reasons. First, the assumption of equilibrium partitioning of chemicals between water and plankton used in the model may not describe bioaccumulation by plankton adequately. This is examined in greater detail below in relation to the Z:W fugacity ratios. Second, any inaccuracy in estimating concentrations in organisms at the base of the food web would be carried forward in estimating concentrations in organisms from higher trophic levels.

Among individual organisms, concentrations in the scavenger amphipod *Anonyx* were the most poorly predicted, being underestimated for all six chemicals examined. Predicted concentrations ranged from 2.5-fold lower for ΣPCB to as much as 65-fold lower than mean measured values for ΣHCH. The high concentrations of POPs found in *Anonyx* are thought to result from their scavenging from carcasses of marine mammals. This could be confirmed by comparing the POPs concentration profiles found in *Anonyx* to those of the more abundant marine mammals. The low predicted concentrations for *Anonyx* probably result from the exclusion of marine mammals from the current steady-state food web model.

The strong correlation between mean measured and predicted concentrations of POPs shown in Figure 1 for marine mammals (male ringed seals and beluga) only resulted after making allowances for biotransformation-enhanced elimination rates which were estimated using the models. Without this, the marine mammal models would overestimate the concentrations of several of the chemicals that are prone to biotransformation processes, notably HCH and HCB in beluga and HCH, HCB and chlordane in ringed seals. Estimated elimination half-lives ranged from 0.5 years for HCB to 6.9 years for ΣDDT in ringed seals, while values ranged from 1.9 years for HCH to about 15 years for ΣDDT and ΣPCB in beluga.

Fugacity Calculations

Water:air (W:A), zooplankton:air (Z:A) and zooplankton:water (Z:W) fugacity ratios were calculated for α–HCH, γ–HCH, HCB, *cis-* and *trans*-chlordane. Representative results are shown for γ-HCH and *cis*-chlordane in Figure 3 on a monthly basis along with annual averages. The W:A ratios were consistent with the values presented by Hargrave *et al.* (1997) and provide an internal check on the calculations performed here. A W:A fugacity ratio value >1 is indicative of a flux of chemical from water to air (outgassing). A value <1 is indicative of deposition from the atmosphere to the water. The fugacity ratio for α-HCH was always >1 suggesting a steady efflux from the sea. Ratios were similar in most months for γ–HCH except May and October when values fell just below 1. HCB ratios were close to 1 throughout the year, the highest value of 2 occurring in June. The highest ratios for α-HCH and γ-HCH also occurred in June and could be attributed to lower air concentrations

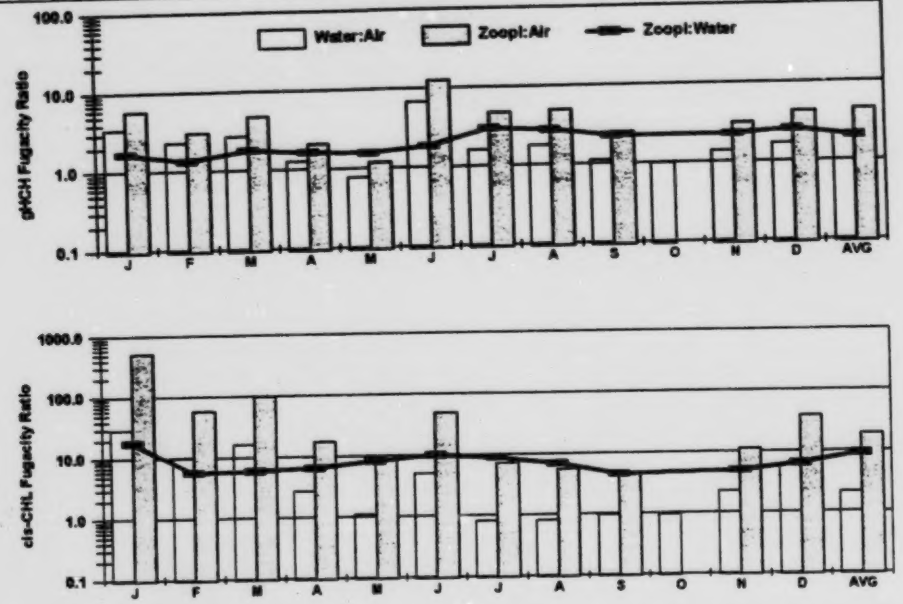

Figure 3. Calculated monthly fugacity ratios between water, air and zooplankton for γ-HCH, and *cis*-chlordane along with annual average values. Water:Air ratios are equivlent to the values from Hargrave *et al.* (1997).

during that month. The W:A ratios for *cis*- and *trans*-chlordane showed strong seasonal fluctuations with values greatly exceeding 1 in many instances and particularly for *cis*-chlordane. Ratios for *cis*-chlordane ranged from 10 to 30 from January to March and declined to values ≤1 from July to October. Ratios then increased in November and December. A similar trend was evident for *trans*-chlordane but ratios were always less than the values for *cis*-chlordane. Except for June, the ratio was <1 from April to November suggesting an extended period of deposition to the sea. The strong seasonal trends for *cis*- and *trans*-chlordane could largely be attributed to decreases in air fugacity during colder months which result from greater partitioning to aerosol particles and higher atmospheric particulate levels.

Zooplankton:Water ratio values exceeded unity in nearly all cases. Annual average fugacity ratios were 4.6 for α-HCH, 2.0 for γ-HCH, 7.1 for HCB, 9.1 for *cis*-chlordane and 8.3 for *trans*- chlordane. These results indicate that the widely held, but rarely tested, assumption that concentrations of organic contaminants in plankton are in equilibrium with water does not appear to apply in the Arctic marine ecosystem for reasons yet to be determined. The magnitude of these deviations from equilibrium conditions clearly demonstrates the need to re-examine bioaccumulation processes at the base of the food web and, if possible, revise that portion of the food web model accordingly. It is emphasized that contaminant bioaccumulation or biomagnification that occurs at the base of the food web ultimately influences the concentrations found in higher trophic levels. These results also snow that the Z:A fugacity ratio cannot be considered as a reliable surrogate for the W:A ratio in estimating chemical fluxes between water and the atmosphere.

Closer examination of the Z:W ratios shows a fairly consistent seasonal pattern with peaks occurring in June and July when there is open water, and again in mid-winter (December and January). The magnitude of seasonal shifts in the Z:W fugacity ratio varies between chemicals, but too few chemicals were examined here to relate them to chemical-physical properties. These seasonal shifts may be accounted for in part by seasonal changes in system productivity and in the lipid content of the plankton. A dynamic contaminant fate and bioaccumulation model would be required to account for the seasonal changes in plankton contaminant levels.

CONCLUSIONS

Overall, the food web bioaccumulation model performed adequately in predicting tissue concentrations within a factor of three for about two-thirds of the observations. Regression analysis showed that the model tended to underestimate the extent of bioaccumulation through the food web. This may have resulted, in part, from underestimating the contribution of benthic contaminant sources to the food web, and also from underestimating the extent of bioaccumulation from water to plankton. For the latter, fugacity calculations showed that the assumption of equilibrium partitioning between water and plankton does not appear to apply in the Arctic marine ecosystem.

Several data gaps and research needs pertinent to this project have been identified. First, data are required to better characterize contaminant levels in sediments and benthic organisms. This would aid in developing a better understanding of benthic-pelagic coupling in the marine food web and the contribution of contaminants in the sediments and benthos to the pelagic food web. Second, additional measurements of low level POPs (e.g. PCB congeners, chlordane, DDT and metabolites) are needed for sea water and plankton to develop a better understanding of bioaccumulation processes at the base of the food web.

Expected Project Completion Date: March 31, 2002.

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ADSORPTION COEFFICIENTS, SPECIFIC SURFACE AREA OF SNOW AND PRELIMINARY FIELD VALIDATION FOR MODELS OF DEPOSITION AND FATE OF ORGANIC CONTAMINANTS AND MERCURY IN ARCTIC AND ALPINE ECOSYSTEMS

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OBJECTIVES

Long-term

1. To further the knowledge of snow and ice-related contaminant transport processes necessary for planning and conducting an intensive study of atmospheric deposition and air-snow pack exchange processes in the Canadian Arctic Archipelago Project, which was tentatively planned for 1999-2000 and 2000-2001 (Bidleman 1997, pers. comm.).

Short-term

1. To extend the available data base of air-ice adsorption coefficients of non-polar organic chemicals to include persistent chlorinated organic contaminants of particular interest in the Canadian Arctic.
2. To measure the air-ice adsorption coefficient for mercury vapour as a function of temperature.
3. To measure the rate of decrease of snow specific surface area as a function of temperature in controlled laboratory experiments.
4. To liaise with other partners with a view to collaborating in field experiments that are designed to validate models of transport and ecosystem uptake, as influenced by snow, of persistent chlorinated organic contaminants (Northern Ontario and Canadian Rocky Mountains) and of Hg (Northern Quebec), with specific attention to the effects of snow specific surface area and of temperature.
5. To extend the available data base on snow specific surface area to include samples of fresh and metamorphosed snow and obtain data on the rate of specific surface area decrease during metamorphosis under natural conditions in the field experiments mentioned in the previous objective.
6. To ensure that the information developed in the above studies is transferred to Northern Contaminants Program (NCP) modellers and used in the planning of snow/ice-related sampling and measurements during the field part of the Canadian Arctic Archipelago Project.

DESCRIPTION

As mentioned at the Arctic Archipelago Project Workshop, models that are currently being used to estimate organic contaminant fate and deposition in Arctic ecosystems are based on "the snow adsorption theory". This theory postulates that the occurrence of the contaminants in snow on the ground is due to physical (reversible) adsorption of vapour phase organic contaminants in the atmosphere onto snow crystal (ice) surfaces. The key parameters in these models are the adsorption coefficients for the contaminants, which depend on the temperature and the vapour pressure of the sub-cooled liquid compound, and the specific surface area of the snow. The snow adsorption theory is supported by laboratory measurements of adsorption of relatively volatile organic vapours onto ice surfaces and of the specific surface area of snow, but the theory has not yet been tested by field experiments. Carefully designed field experiments are ultimately necessary for validation of these models.

One approach is to design field experiments to test specific hypotheses motivated by the theory. For example, one can hypothesize from this theory that certain low vapour pressure contaminants will be almost completely removed from the air mass through which the snow falls before the snow touches the ground surface. Assuming that the air through which the snow falls is stagnant (simple one-box model), one would expect that the contaminant concentrations observed at ground level would decline exponentially in both media (air and snow) during the snowfall event. The alternative hypothesis, that the contaminants are incorporated in the ice lattice during the in-cloud formation of snow, would presumably give rise to a different expectation. A field experiment designed to test this hypothesis might thus involve measuring concentrations in snow and air several times throughout the course of a snowfall event. This requires that the time scale of the snow and air concentration measurements is small relative to the duration of the snowfall event. If ambient air temperature and snow specific surface area are expected to vary during a snowfall event, one would also want to measure these auxiliary variables. Another strategy might be to measure time-integrated snow and air concentrations for a number of events, together with temperature and surface area. One would expect from the adsorption theory that variations in the magnitude of the scavenging ratio (snow concentration : air concentration) between snowfall events would be correlated with specific surface area and anti-correlated with temperature. The adsorption theory can also be used to estimate the absolute magnitude of the scavenging efficiency; the accuracy of the estimate depends on that of the adsorption coefficient, which can be estimated but has not yet been measured for the contaminants of interest.

Another prediction of the snow adsorption theory is that the freshly deposited contaminants will tend to diffuse out of the snow deposit and back into the atmosphere after a snowfall event. There are several reasons for this. Below-cloud scavenging is a dynamic process and adsorption is reversible, so there will be a concentration gradient in the snow deposit initially after deposition ceases, and this gradient will slowly relax. On a longer time scale, the specific surface area of the snow will also tend to relax (decrease) during metamorphosis. The capacity of the snow to retain contaminants will of course decrease in proportion to the decrease in surface area. There have been no measurements, to our knowledge, of the temperature-dependent rate of decrease of the specific surface area of natural snow. This can be estimated from experiments (e.g. done by Jellinek and Ibrahim in the 1960s) which used a large surface area (approximately 10 $m^2 \cdot g^{-1}$) ice powder made by spraying purified water into liquid air. However, this estimated rate is probably too large, because natural snow probably has a specific surface area much less than 10 $m^2 \cdot g^{-1}$. Furthermore, several processes are responsible for the rate of change of specific surface area during metamorphosis. These processes are: (i) the grain-to-grain migration (by evaporation and condensation) of water vapour, which is driven by the temperature gradient in the snow deposit; (ii) the effect of curvature of snow crystals (higher vapour pressure is associated with greater curvature); and (iii) sintering of the snow crystals (Sam Colbeck, pers. commun.). These processes occur on different time scales, and the first process, which involves an input of energy, can actually produce new ice crystals that have smaller dimensions than their precursors. It is therefore difficult to predict the rate of surface area decrease during metamorphism without performing a series of experiments in the laboratory under carefully controlled conditions, and by eventually comparing the experimental results with measurements done in the field.

To our knowledge, there have not yet been any studies of the chemical mechanisms by which mercury (Hg) is incorporated in snow, despite the obvious importance of snow for removing Hg from the Arctic atmosphere and despite the toxicological importance of Hg. The lifetime of Hg in the earth's atmosphere has been estimated to be in the neighborhood of 0.5 to 2 years, so air concentrations are generally constant. Mercury exists in the atmosphere primarily as elemental Hg^0 vapour. Precipitation scavenging is thought to be the main sink for Hg in the atmosphere. The Henry's Law coefficient for Hg^0 is such that very little of it will partition into water, but mercury concentrations in rainwater are orders of magnitude larger than predicted from the Henry's Law constant. It is believed that Hg^0 is oxidized to Hg^{2+} by ozone in cloud water; the homogeneous gas phase oxidation of mercury by ozone is thought to be less important. It is also known that surfaces can promote reaction of Hg^0 with ozone, and it is logical to suppose adsorption is a necessary first step. Therefore, it is reasonable to suppose that ice surfaces may promote the oxidation of Hg^0 in the atmosphere, and this may be a contributing mechanism to scavenging of mercury from the Arctic atmosphere. Ice surfaces may also be important in the depletion of mercury vapour from the atmosphere during polar sunrise.

An understanding of the mechanisms by which mercury is removed from the Arctic atmosphere by snowfall is obviously required for modelling the deposition of Hg and its subsequent fate in snow deposits. This understanding may shed further light on questions such as the relative importance of natural and anthropogenic sources. Due to the low vapour pressure and low solubility in water of mercury, adsorption of Hg^0 on snow crystal surfaces is also a possible removal mechanism for the Arctic atmosphere. One can estimate the adsorption coefficient for mercury vapour at the air-water interface by assuming that elemental mercury behaves like a non-polar organic molecule. However, this assumption would probably be incorrect. Because the surface tension of liquid mercury is greater than that of water, one would expect a *negative* Gibbs surface excess concentration at the air-water interface. However, based on the vapour pressure and heat of vapourization, mercury would be expected to adsorb on the surface of ice, and an adsorption coefficient in the range for semi-volatile organic compounds would be expected. There have not been any measurements, to our knowledge, of the adsorption of mercury vapour onto the surface of ice.

ACTIVITIES IN 1998/1999

Snow specific surface area measurements

The frontal chromatography method that was described in the previous NCP synopsis report (Hoff and Wania 1999), was further tested and evaluated. The method was also applied to snow samples taken from two remote locations, and to a sample of synthethic snow (ice powder) that was prepared in the lab for use in developing a method for measuring K_{IA} values for semi-volatile organic chemicals on the surface of ice. The main goal of these studies was to further validate the frontal chromatography method for measuring snow specific surface area (SSA) and to demonstrate that the method is sensitive enough to accurately measure SSA for samples of metamorphosed snow.

Adsorption coefficient K_{IA} measurements

During the 1998/99 fiscal year, an attempt was made to develop a new method for measuring adsorption coefficients for semi-volatile organic compounds on the surface of ice. The work was carried out by a team of two fourth-year chemistry students and two of the project team members (J. Hoff and T. Gorecki).

RESULTS

Snow specific surface area method

The frontal chromatography method was used to measure sorption of ethyl acetate and n-decane by water-coated Chromosorb P over the temperature range of -13°C to 20°C. Water-coated Chromosorb P was used to simulate the air-water/ice interface, because the interfacial surface area can be varied by controlling the water content (Hoff *et al.* 1993). Another advantage of using wetted Chromosorb P instead of ice powder is that sorption of decane can be measured at temperatures above 0°C. Prior studies indicated that the surface area of wetted Chromosorb P does not change when frozen, however, a slight increase in the temperature dependence of K_{IA} was observed (Hoff *et al.* 1995).

The experimental apparatus is basically a gas chromatograph that is set up for frontal chromatography measurements. A schematic diagram is shown in Figure 1. The main components are: (1) a device for producing humidified carrier gas; (2) a device for producing a low concentration of chemical vapour in the humidified carrier gas; (3) a glass column containing snow, ice powder or wetted Chromosorb P; (4) a four-port gas switching valve, which is used to control whether pure carrier gas, or carrier gas containing chemical vapour, enters the snow column; (5) a flame ionization detector, which monitors the concentration of methane or chemical vapour in carrier gas coming from the snow column; (6) a constant temperature bath, which can be operated between +25°C and -25°C; (7) a pneumatic flow controller used to keep the carrier gas flow rate constant; (8) an inline electronic flow meter used to monitor the flow rate of carrier gas that supplies the apparatus (total flow rate); (9) a bubble flow meter used to monitor the flow of carrier gas that bypasses the snow column; and (10) a modified Tee union, which enables a pulse of methane to be injected into the snow column.

The procedure for measuring sorption of chemical vapours by water-coated Chromosorb P is as follows. Distilled water is added to a bottle containing dry Chromosorb P. The wetted Chromosorb P used in the experiment had a water content of 0.406 g water per g of wetted Chromo P. The bottle is tightly sealed and stored at 60°C for at least 10 h. Approximately 31 g of the water-coated Chromosorb P is packed into the glass column, which has an empty volume of approximately 54 mL. The glass column is immersed in the temperature bath, and a carrier gas flow rate of approximately 35 $mL \cdot min^{-1}$ is established. The back-pressure on the bypass line is adjusted with a needle valve so that the carrier gas flow is divided approximately equally between the two flow paths. In the valve position shown in the diagram, flow from the bypass line enters the snow column and detector, while flow from the chemical vapour source goes to the needle valve and bubble flow meter. In the other valve position, the valve routes flow from the bypass line to the needle valve and bubble flow meter while the flow from the chemical vapour source enters the snow column and detector.

After thermal equilibrium is established at -10.5°C and the detector signal has stabilized, the detector signal is recorded and a pulse of methane is injected into the snow column with a gas-tight syringe. After the methane pulse has eluted, the gas valve is switched so that a sharp front of chemical vapour enters the column. After the front has eluted, the gas valve is switched again and a reverse front enters the column. The recorded detector signal is analysed on a spreadsheet to obtain the first moments for the methane pulse t_M and the chemical vapour front t_R. The net retention volume V_N is calculated as $V_N = k' V_M$, where k' and V_M are the column capacity factor and the dead volume of the snow column, respectively. k' is calculated as $(t_R - t_M) / t_M$ and V_M is calculated as (empty volume) – (volume occupied by sorbent). The latter is calculated from the density of the sorbent. V_N is related to the adsorption coefficient K_{IA} and surface area (SA) of the sorbent according to $V_N = K_{IA}$ SA.

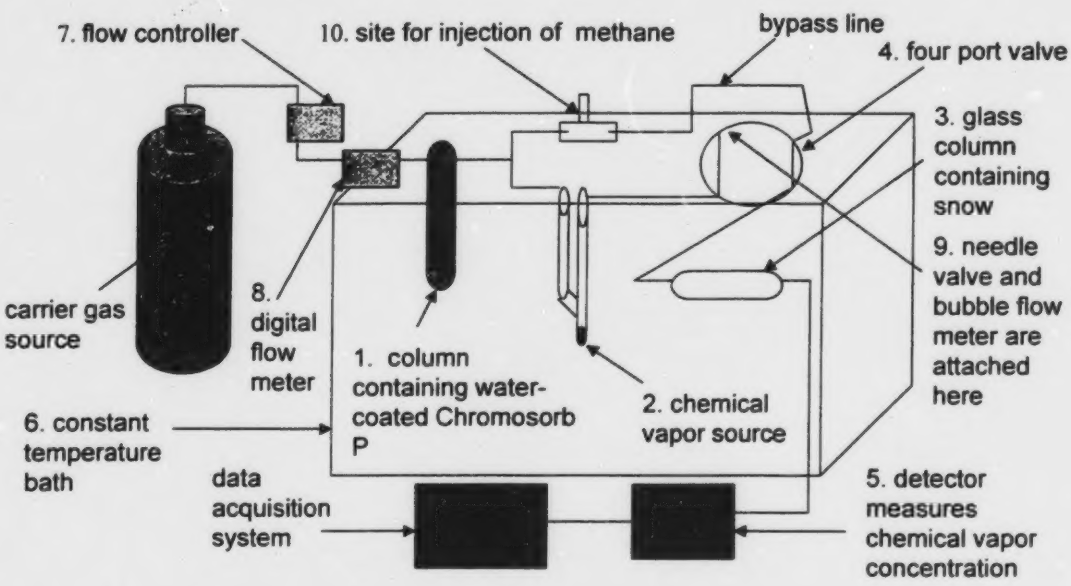
7. flow controller
10. site for injection of methane
bypass line
4. four port valve
3. glass column containing snow
9. needle valve and bubble flow meter are attached here
carrier gas source
8. digital flow meter
1. column containing water-coated Chromosorb P
2. chemical vapor source
6. constant temperature bath
data acquisition system
5. detector measures chemical vapor concentration

Figure 1. Snow specific surface area apparatus.

Typical adsorption and desorption breakthrough curves for ethyl acetate were shown in Figure 1 of Hoff and Wania (1999). The first moments for adsorption and desorption fronts are equal within experimental error. The lack of hysteresis indicates that that sorption and desorption is very rapid, which is consistent with the hypothesis that the sorption mechanism is adsorption. The methane injection method of determining the dead volume gave 20-30% larger values than the calculated method. Apparently, this is due to a systematic error in measuring the flow rate to the detector, which was calculated as the difference between the electronic (total) flow rate minus the bubble (bypass) flow rate. The calculated method is believed to be more accurate, and is therefore used here.

Net retention volumes for n-decane were measured at temperatures of 0.4, 11.5 and 20°C, and the values obtained were 95.9, 39.2 and 19.9 cm^3, respectively. These data yield the equation $\ln V_N = 6433 / T - 18.95$ ($R^2 = 0.9997$), which is used to calculate a net retention volume of 35.7 cm^3 at 12.5°C. Using the literature K_{IA} value for 12.5°C (Hartkopf and Karger 1973) and the equation $V_N = K_{IA}$ SA, the estimated SA of the wetted Chromosorb P is 69 000 cm^2, and the SSA is 2270 $cm^2 \cdot g^{-1}$. Net retention volumes for ethyl acetate were measured at temperatures of -13,-8, -5, -4.5 and -1.2°C, and the values obtained were 1152.4, 717.0, 469.9, 440.0 and 421.1 cm^3 respectively. These data yield the equation $\ln V_N = 6800 / T - 30.27$ ($R^2 = 0.93$), which together with the SA calculated above yields a K_{IA} value of 0.0125 cm for ethyl acetate at -10.5°C.

Snow specific surface area method application

Synthetic snow was prepared in a freezer room (-15°C) by spraying distilled water through a nozzle to produce a fine mist, which fell into an aluminum tray containing liquid nitrogen. The product was examined with a hand-held microscope at a magnification of 30x. It consisted of clusters of 10 to 30 spherical particles, which had diameters in the range of 0.1 to 1.0 mm. The SSA values obtained for artificial snow were 499 $cm^2 \cdot g^{-1}$ for a fresh batch, which was measured one day after it was made, and 350 $cm^2 \cdot g^{-1}$ for another batch, which was allowed to age in a freezer at -18°C for 3 weeks before the SSA was measured.

Snow samples were collected during late February of 1998 at Bow Lake in Banff Park, Alberta by J. Blais and Derek Muir. The samples were taken at two "lysimeter sites", one of which was located in a forested area and the other in a clearing approximately 2 km from the forested site. The samples were taken using a core tube, so that the full snow pack was collected and integrated, and placed in heavy gauge polyethylene bags, which were then placed in a very large cooler with dry ice. The cooler was shipped by air to the University of Waterloo, and it was stored in a freezer room at -10°C while the SSAs were being determined. This was accomplished within 10 days. The snow was highly metamorphosed, and examination with a 10x hand lens revealed rounded snow grains with diameters in the range of 0.05-0.10 cm. Assuming that the grains are spherical, the geometrical surface area ranges from 60-120 $cm^2 \cdot g^{-1}$, which is consistent with the SSAs tentatively reported in the previous synopsis of NCP research (Hoff and Wania 1999), which were 89 and 104 $cm^2 \cdot g^{-1}$ for the forested and open Bow Lake samples. However, these SSA values were calculated using an estimated K_{IA} value for ethyl acetate, which, as mentioned above, is probably too large by approximately a factor of 2. The SSAs for the forested and open Bow Lake snow samples should therefore be revised to 183 and 214 $cm^2 \cdot g^{-1}$, respectively, to be consistent with this more accurate experimental value for K_{IA}.

Snow samples were collected during early February, 1999 at the Turkey Lakes experimental field site near Sault Ste Marie, Ontario by Graham LaHaie in cooperation with W. Strachan. The main objective was to determine whether the concentrations of chlorinated organic pesticides decrease in the snow pack several days after falling due to a decrease in snow surface area. To test this hypothesis, 6 aluminum trays were put down before a snowfall. Three trays were sampled immediately after the fall, and the other three trays were sampled 10 days later. The snow samples were sent to the University of Waterloo for SSA determination and to the Canada Centre for Inland Waters (CCIW) for chemical analysis. The SSA samples were placed in plastic Tupperware containers, which were placed in a well-insulated Coleman cooler packed with dry ice. The cooler was shipped by air to the University of Waterloo, whereupon it was stored in a freezer room at -10°C until SSA was determined 3 to 4 days later.

In all, two shipments containing 3 samples each were analysed for SSA during the 1998/99 fiscal year. The first shipment contained samples that were collected on February 5, 1999, immediately after a snowfall event that amounted to 19 mm of snow water equivalent. These samples were stored for two days at -20°C in a chest freezer at the Turkey Lakes site before being shipped to the University of Waterloo. A second shipment of snow for SSA analysis was collected on February 15, 1999 from a duplicate set of 3 trays that were put down at the same time as the first set of trays. These samples were shipped immediately after collection. A polyethy-lene roof, installed over the sampling trays after the snowfall event, protected the snow in the second set of trays from a subsequent 13 mm precipitation event, which occurred on February 11. Approximately 60% of the precipitation was rain. The samples for SSA were taken from the top-most layer of snow in the trays, which did not seem to be disturbed, but the samples for pesticides were not taken due to the fact that the bottom layer of snow was either partially melted or infused with water from outside the trays. The SSA values obtained from the first sampling were 668, 689 and 675 $cm^2 \cdot g^{-1}$, and those for the second sampling were 677, 666 and 678 $cm^2 \cdot g^{-1}$. The average values of 677 and 674 $cm^2 \cdot g^{-1}$ for the fresh and aged samples, respectively, do not indicate a significant decrease in SSA due to aging.

Adsorption coefficient K_{IA} measurements

The experimental approach was to equilibrate a synthetic snow (ice powder) of known surface area with a stream of nitrogen gas containing a mixture of contaminants. The normal alkanes $C_{11}H_{24}$ through $C_{28}H_{54}$ were used as model contaminants. The contaminant concentrations in the carrier gas emerging from the column of the ice powder were monitored by quantitatively trapping them with a C_8H_{17}-bonded silica column (Harner *et al.*, 1996). After establishing the contaminant concentrations that were in equilibrium with the ice powder, clean carrier gas was used to elute the alkanes from the ice powder. By comparing the quantities of alkanes trapped by the C_8H_{17} column during this elution step with those trapped before, the K_{IA} values can, in principle, be calculated. Gas chromatography was used to quantify the contaminant concentrations in hexane used to elute the C_8H_{17} column. The surface area of the ice powder was determined by the frontal chromatography method described above.

Although the work did not continue until the first K_{IA} values were obtained (it ended when the students completed their advanced lab course and the allocated budget was exhausted), the apparatus was constructed, and some of the basic techniques (e.g. use of a C_8H_{17} column to measure contaminant concentrations in nitrogen) were tested. In all, a significant amount of progress was made in developing the new method.

DISCUSSION AND CONCLUSIONS

The present K_{IA} value for ethyl acetate on ice, 0.0125 cm at -10.5°C, is larger than the previously estimated value, 0.027 at -11°C, by a factor of two (Hoff and Wania 19[illegible]9). The previous value was estimated using the K_{IA} value for 25°C (Hoff *et al.* 1993) and by assuming that the heat of adsorption is equal to the heat of condensation. The present value is considered to be more accurate and is therefore preferred. Previously reported SSAs for snow samples therefore need to be revised. For the snow aging study (Figure 2 in Hoff and Wania 1999), the SSA values for fresh snow samples are revised to 1100-1300 $cm^2 \cdot g^{-1}$, and the SSA value for the sample aged 4.5 days is revised to 600 $cm^2 \cdot g^{-1}$. For the slightly aged snow samples from Turkey Lakes the range is 600 to 700 $cm^2 \cdot g^{-1}$. These values are within the range of values obtained for fresh snow using N_2 adsorption (Hoff *et al.* 1998). For the highly metamorphosed samples from Bow Lake (Hoff and Wania 1999), the revised SSA values are 183 and 214 $cm^2 \cdot g^{-1}$, which are significantly smaller than those for the fresh or slightly aged samples, supporting the hypothesis that SSA decreases during metamorphosis. The SSA values of synthetic snow prepared in the laboratory fall within the range of the natural samples.

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LONG-RANGE TRANSPORT OF CONTAMINANTS TO THE CANADA BASIN AND SELECTIVE WITHDRAWAL THROUGH THE CANADIAN ARCHIPELAGO

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Project Team: Mary C. O'Brien, Darren Tuele, Doug Sieberg and David Paton, IOS, Sidney, BC

OBJECTIVES

Long-term

1. To understand the Arctic Ocean's role in contaminant transport and accumulation in the Canada Basin and the downstream selective withdrawal of these contaminants into the Canadian Archipelago.

Short-term

2. To analyse archive samples collected along the Joint Ocean Ice Studies (JOIS) (September 1997) cruise track through the Canadian Archipelago to the Surface Heat Budget of the Arctic (SHEBA) site in the Canada Basin interior (Figure 1).

DESCRIPTION

The results of recent Northern Contaminants Program (NCP) research (Barrie *et al.* 1997) indicate that the highest concentrations of HCHs in the Arctic Ocean are observed within the Canada Basin interior. In the early 1990s, the surface waters of the Canada Basin contained the highest concentrations in the world's oceans – concentrations which were 4-10 times higher than, for example, Pacific or Atlantic waters now entering the Arctic. HCH concentrations in bodies of water that can exchange with the atmosphere, such as those found in the source regions of the Bering Strait and Fram Strait and in seasonally ice-free shelf regions, reflect a downturn in atmospheric concentrations (Barrie *et al.* 1997). However, high HCH concentrations persist in the Canada Basin interior and are the result of a combination of factors: atmospheric concentrations that peaked nearly twenty years ago; the slow renewal time of upper layer waters in the Canada Basin; and the presence of a near-permanent ice cover (Macdonald *et al.* 1997). These high concentrations are found in the upper 200 m of the water column – the region most closely associated with biological activity. The Canada Basin time series station is unique; it provides an opportunity to observe the ocean's response to the atmospheric downturn in HCH concentrations that occurred in the early 1990s, and thus, to estimate the residence time of this high HCH reservoir.

Sometime between 1989 and 1993, the location of the Atlantic-Pacific water mass boundary changed from the Lomonosov Ridge to the Alpha-Mendeleyev Ridge (McLaughlin *et al.* 1996). This shift signalled a displacement of the upper 200-300 m of Pacific-origin waters from the Makarov Basin. The significance to Canada is that the most likely route for the exit of this water is through the Canadian Archipelago and, as discussed above, the water contains a potentially large inventory of contaminants.

The strength of our HCH contaminant sampling program is that it has been integrated with other broad science plans. This means that contaminant distributions can be interpreted and modeled within the full context of physical, chemical and biological processes, and of atmospheric and oceanic transport mechanisms. Clearly this approach is of far greater value for understanding the ocean's role in the perstistence of globally transported contaminants than that of sampling that is isolated in time or space.

ACTIVITIES IN 1998/99

Samples collected during the Joint Ocean Ice Studies (JOIS) 1997 mission for HCH profiles, together with samples of arctic cod and zooplankton, were analysed for organochlorine concentrations. Geochemical data collected at the same time have also been collated.

RESULTS

Samples for organochlorine determination were collected along the JOIS 1997 track, including stations within the Archipelago and along a section out to the SHEBA deployment location (Figure 1). Sections and vertical profiles for HCH have been completed and are undergoing interpretation. Data are now also available for biota but have not yet been synthesized.

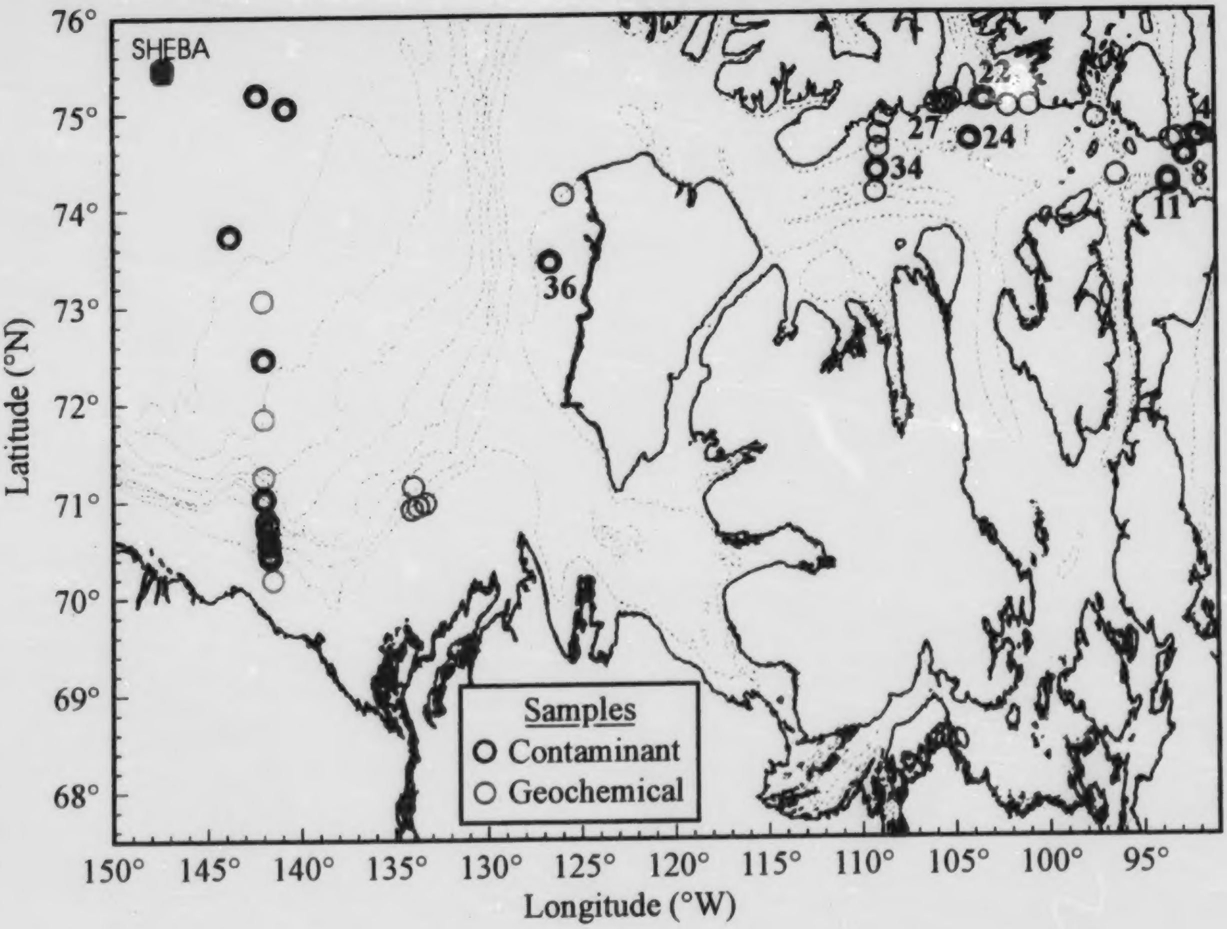

Figure 1. Location of sampling sites for JOIS-97. All stations where geochemical data have been collected are shown in red; stations where contaminant data were collected are circled with black.

DISCUSSION/CONCLUSIONS

The HCH profiles from the Archipelago (Figure 2) show typically elevated concentrations in the upper 100 m of the water column. Surface α-HCH concentrations of 3500-4000 $pg \cdot L^{-1}$, to the west of Resolute (Stations 24, 27, 34 and 36), agree well with the observations of Hargrave *et al.* (1997) and suggest that levels in this region have not dropped much since 1996. We infer that the decreasing trend from January to December found by Hargrave *et al.* (1997) has not been maintained; concentrations have either remained constant or even increased slightly since that time. In contrast, the low surface α-HCH concentrations found to the east of Resolute on the north side of Barrow Strait (Stations 4 and 8) suggest that there is considerable lateral variability in the channels, something that has been anticipated from the complex circulation patterns. We are examining the geochemical data in order to unravel the reasons for the HCH spatial variability.

Station 34 in Viscount Melville Sound is located in a basin. The deep water at this station, which has an anomalously old ventilation age as indicated by CFC measurements, seems also to show a discontinuity in the HCH profile at about the 200 m depth (Figure 2). Clearly, this basin contains HCH exchanged at an earlier time and therefore provides an excellent site to seek evidence of *in-situ* removal processes.

The section across the Canada Basin margin (Figure 3) shows an obvious boundary between coastal water (Stations 2, 3 and 4), which has reduced α-HCH concentrations, and interior water (Stations 5+). To further complicate this appealing pattern, Stations 10 and 14, which are well within the pack, also exhibit anomalously low surface concentrations. The geochemical evidence suggests that surface stratification may play a role by preventing the atmospheric exchange process at some sites and not

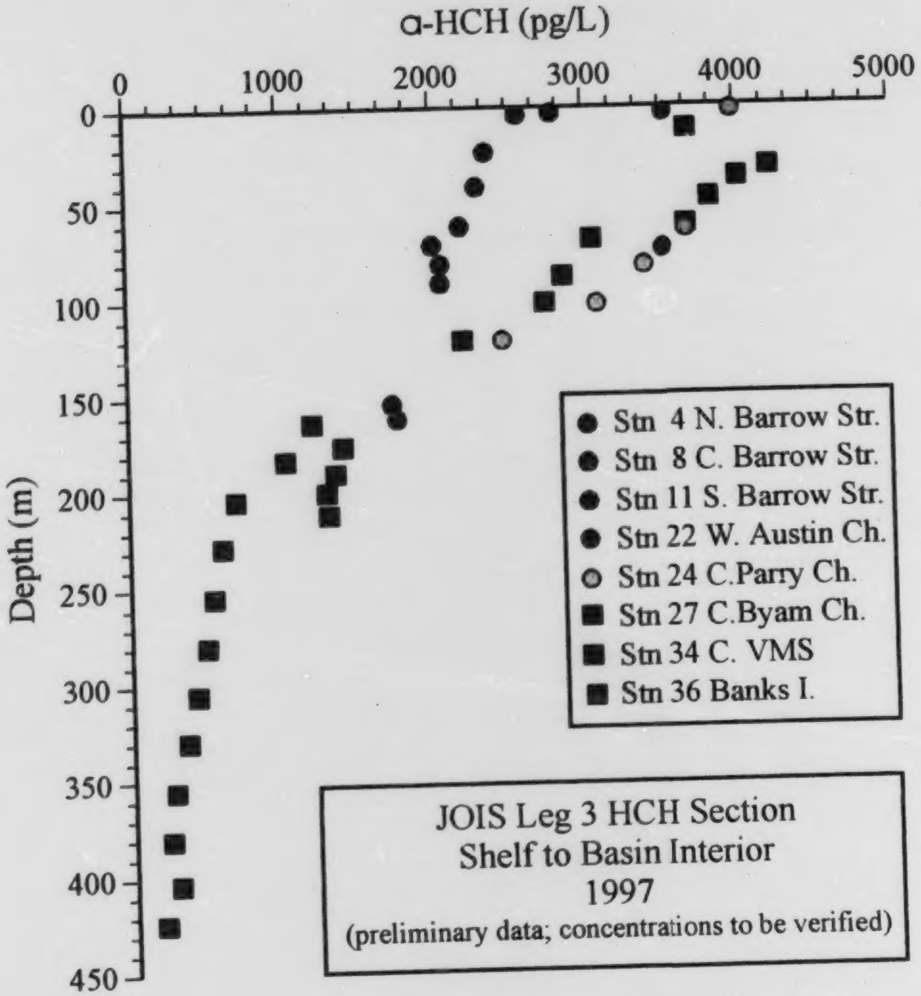

Figure 2. Verticle profiles for α–HCH from the Archipelago stations in 1997. Station numbers in the inset box are also identified in Figure 1.

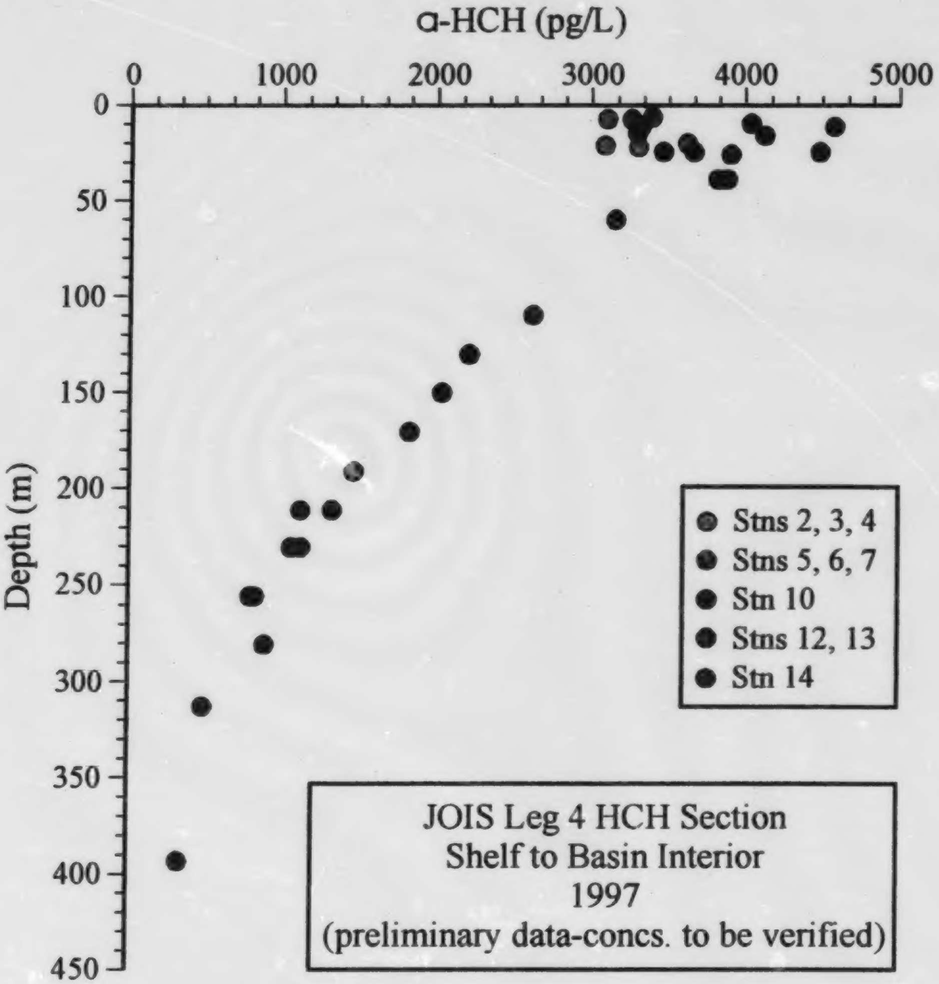

Figure 3. Vertical and horizontal α–HCH data for the section out to the SHEBA deployment site (see Figure 1, westernmost transect).

at others. Stratification is not uniformly distributed across the section and is partly controlled by run-off and partly by ice-melt (Macdonald *et al.* 1999). Alternatively, the patchiness evident in Figure 3 may reflect the exchange of water masses from the margin into the interior, something that we hope to resolve by examining the geochemical data. Further HCH determinations and biological tissue analyses should help to resolve this puzzle.

Expected Project Completion Date: April 30, 1999.

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THE SEASONAL CYCLE OF ORGANOCHLORINE CONCENTRATIONS IN THE CANADA BASIN

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Project Team: Eddy C. Carmack, David Paton, Mary C. O'Brien, Darren Tuele and Doug Sieberg, IOS, Sidney, BC; Harold Welch, FWI, Winnipeg, MB

OBJECTIVES

1. To measure the intra-annual variability of contaminant transport and food-web accumulation in the Canada Basin from October, 1997 to October, 1998 from the drifting platform provided by the Canadian Coast Guard Ship (CCGS) *des Groselliers* and SHEBA.

DESCRIPTION

SHEBA (Surface Heat Budget of the Arctic), a year-long drift station in the Beaufort Sea, provided a unique opportunity to examine the physical and biological processes that support high contaminant concentrations in top predators of the Arctic Ocean. The Beaufort Gyre can be considered to be a large, relatively isolated ice-covered "mesocosm" in the interior Canada Basin. Previous work has shown this region to contain high concentrations of HCH (Hargrave *et al.* 1988, Macdonald *et al.* 1997) and it was suspected that other pesticides with low Henry's Law constant might similarly be enriched. During the *Canadian Arctic Contaminants Assessment Report* (CACAR) review, several factors contributing to this region's sensitivity to persistent organic pollutants (POPs) were identified, including cold water, ice cover and low particle fluxes in the water (Barrie *et al.* 1997). Furthermore, it has become clear that the surface ocean of the Canada Basin is a large reservoir that cannot easily shed its contaminants and which will, therefore, affect downstream locations (especially the Canadian Archipelago) for years to come.

The SHEBA platform (CCGS *des Groselliers*) was therefore used as a base from which to conduct a year-round contaminant measurement program (see Macdonald *et al.* 1999a for sampling plan). In particular, samples were collected at six intervals during the SHEBA drift (Figure 1) to measure POPs concentrations in air, water, suspended particulates, ice and biota, with the intention of observing how the ocean maintains contaminant burdens in the euphotic zone and how such contaminants transfer into the food web. The sampling components included water and ice, particles, algae, zooplankton (sorted) and fish. The samples retrieved during SHEBA will provide information about the relationship between seasonal ice formation and melt, seasonal atmospheric transport and water column organochlorine concentrations in the Canada Basin and the coupling of water-borne contaminants into and up the food chain. Because personnel remained on the platform throughout the year's drift, there was an opportunity to collect large-volume samples using Infiltrex pumps and filters to yield valid data for organochlorines (OCs) of concern like PCBs, chlordane and toxaphene. A full biological program allowed the collection of many different species which could be sorted on site into trophic levels. Analysis of stable isotope composition ($\delta^{13}C$, $\delta^{15}N$) and OC concentration will allow a detailed look at the distribution of OCs as a function of trophic level and/or predator-prey relationships. Finally, physical and chemical data collected during the drift will allow the interpretation of OC data in the context of oceanographic processes which include seasonal stratification/destratification and regime changes (fronts) experienced during the drift. Data such as these are impossible to collect from ships carrying out transects, simply due to time constraints, and are, therefore, noticeably absent from recent assessments (e.g. Barrie *et al.* 1997, AMAP 1998). Ultimately, contaminant distributions can be interpreted and modeled within the context of physical, chemical and biological processes occurring at the site.

The seasonal influence of ice cover was expected to dominate during the SHEBA drift, whereas advection was expected to be less important. Therefore, it was anticipated that SHEBA would mimic a large mesocosm representative of the interior surface pool of the Beaufort Gyre. However, nature surprised us and SHEBA drifted rapidly at times and actually exited the Canada Basin to drift over the Chukchi Cap for 6 months (~ January-August) before re-entering deep water late in the program (Figure 1). Perhaps, a change in large-scale atmospheric pressure field (Arctic Oscillation) that occurred in the early 1990s affected the drift pattern and ice distribution in the Beaufort Sea.

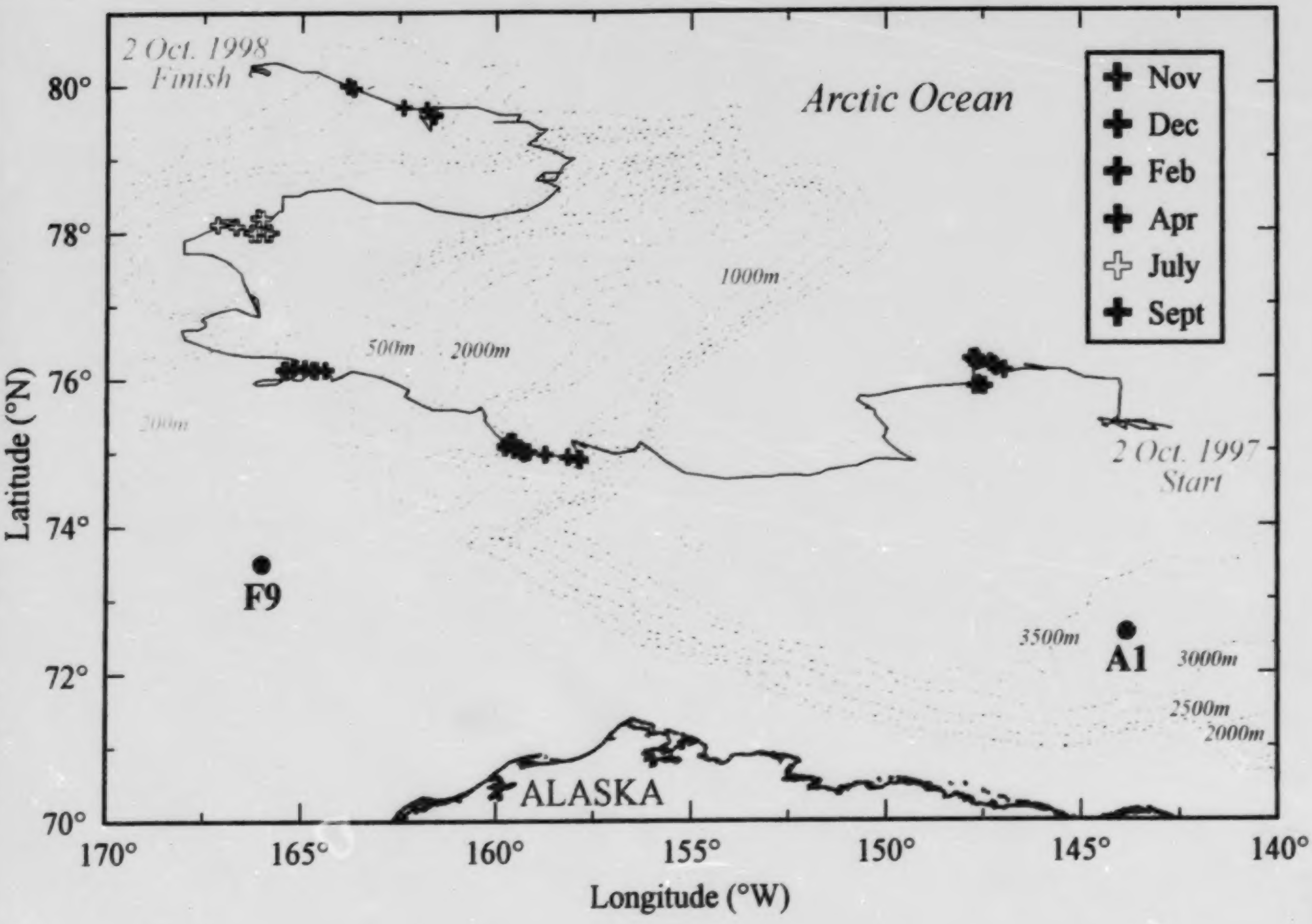

Figure 1. The drift path of SHEBA from October, 1997 to October 1998; sample intervals for this study are shown as coloured segments.

ACTIVITIES IN 1998/99

SHEBA started its drift in October of 1997. Samples were collected during the launch and some were analysed during 1997/98. Further suites of samples were collected during December 1997, February 1998, April 1998, July 1998 and September 1998. Some of these samples have been analysed but many remain to be completed and the work of synthesizing the data has only just begun. Similarly, much of the oceanographic and biological data remain to be analysed and/or interpreted. In April 1998, a sampling team was sent up to the site to conduct a complete sampling program and to recover and re-deploy moorings. Finally, in October 1998, the SHEBA site was joined by the CCGS *Louis S. St Laurent*, the *des Groselliers* was re-activated, SHEBA was recovered, and samples were returned to Quebec. All samples have since been shipped to the Freshwater Institute (FWI) and/or the Institute of Ocean Sciences (IOS) where they are well into the process of analysis.

RESULTS

A large number of samples (physical, chemical, biological and contaminant) have been collected, some analyses have been completed and many remain to be done. As noted above, a regime shift occurred at the beginning of the 1990s and the last two years have witnessed extraordinary ice conditions (Macdonald *et al.* 1999b). Not only has there been much open water in the Canadian Basin margin, but ice has generally been thinner (Welch 1998) and the surface ocean has been much fresher. Water column measurements suggest that during SHEBA there were enhanced amounts of both ice melt and river water; satellite imagery and geochemical data strongly implicate the Mackenzie River as the source of much of the freshening.

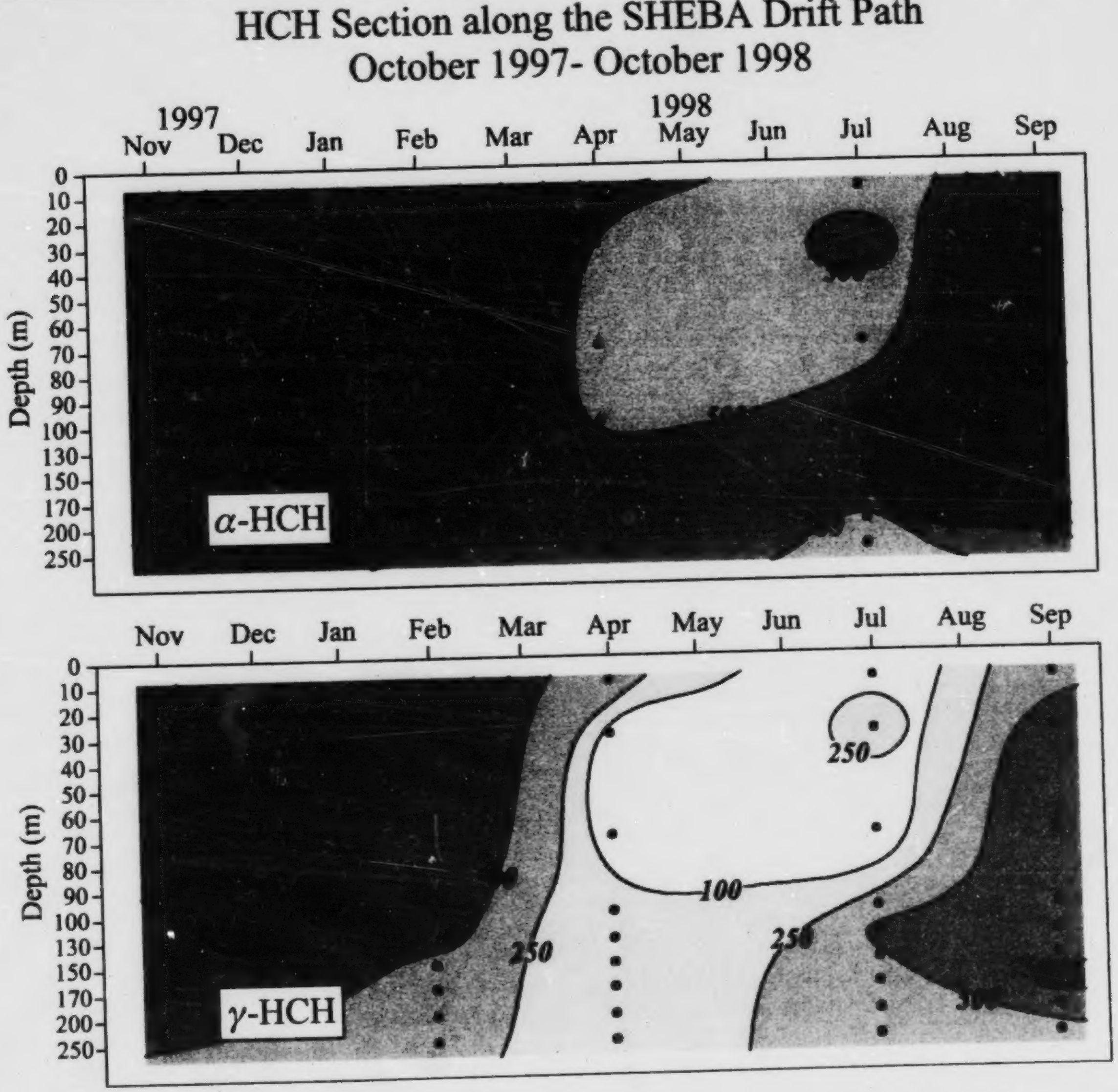

Figure 2. A) A section of α-HCH along the drift path (Figure 1) for the top 250 m of the water column, and B) A section of γ-HCH along the drift path.

DISCUSSION/CONCLUSIONS

Preliminary examples of data emerging from this program are the sections for α-HCH and γ-HCH along the SHEBA drift path shown in Figures 2a and 2b. These figures reveal startling changes in HCH water-column concentration during the year – changes that will only be fully understood after a complete evaluation of the supporting data. Examining the α-HCH section (Figure 2a), we can see that the concentrations early in the drift (November-December 1997) were about 2000-3600 pg·L^{-1}. These samples, taken from the interior of the Canada Basin, are significantly lower than the approximately 6000 pg·L^{-1} determined in the late 1980s and early 1990s (Figure 3; Hargrave *et al.* 1988, Macdonald *et al.* 1994, 1997). Assuming that the decrease in α-HCH is a response of the upper ocean to the dramatic atmospheric decrease during the early 1990s which forced a reversal in the air-sea exchange direction (Li *et al.* 1998, Jantunen and Bidleman 1995) we can estimate a half-life of α-HCH in surface waters of the Canada Basin of about 6 years. This half-life would include losses by advection, sedimentation, exchange with the atmosphere, hydrolysis and microbial degradation.

The remarkable decrease in HCH concentration that occurred sometime between February and April of 1998 (Figure 2) coincides with the drift of SHEBA onto the Chukchi Cap (Figure 1). Water properties changed at

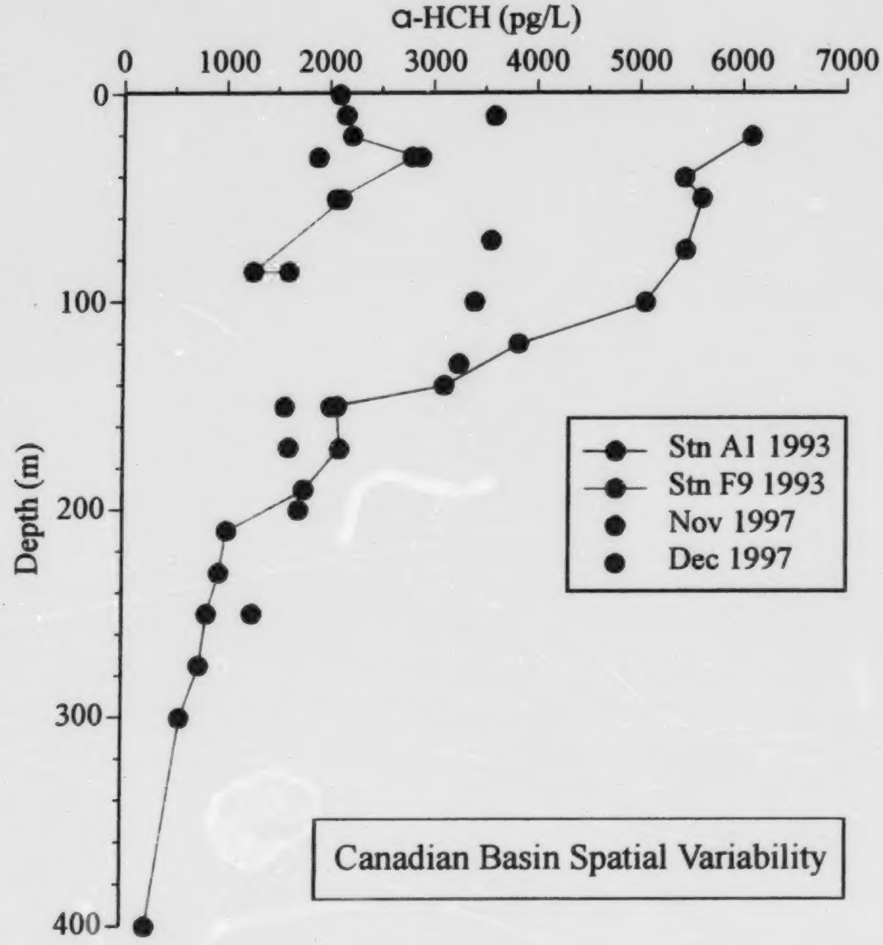

Figure 3. A comparison of α-HCH vertical profiles collected during SHEBA with those collected in the region during 1993 (cf. Macdonald et al. 1994).

this time and we can be certain that SHEBA drifted across a front that separated the interior basin waters from coastal or Bering Sea water toward the basin margin. The change in HCH concentration, therefore, appears to reflect a shift from from the basin interior where there is a permanent ice cover to the shelf where there is seasonal ice cover, rather than HCH degradation or uptake in the water. This observation agrees with previous data that show the Bering Sea to contain lower concentrations of HCH (Barrie *et al.* 1997). Confirming this interpretation, we see the return to higher values that occurred in September 1998 as SHEBA drifted back into the basin (Figure 2). This section illustrates that exchange between marginal water in the Chukchi Sea with interior basin water is one mechanism whereby the HCH concentrations will be reduced within the Canada Basin. How the biota respond to these changes, and what proportion of the HCH and other POPs resides in the biota will be investigated as further analyses become available. The γ-HCH section (Figure 2b) shows the same major features as the α-HCH suggesting little variation in γ/α ratio.

Expected Project Completion Date: March 31, 2000.

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ATMOSPHERIC MERCURY MEASUREMENTS AT ALERT

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Project Team: Alexandra Steffen, Julia Lu, Pierrette Blanchard and Len Barrie (AES);
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OBJECTIVES

1. To obtain baseline ambient air concentration data of total gaseous mercury (TGM) at Alert for the purpose of establishing:
   (i) ambient air concentrations in the Canadian Arctic and their linkage to elevated levels of mercury (Hg) in the Arctic food chain;
   (ii) temporal variability and trends in the high Arctic; and
   (iii) emission sources through the study of long range transport of this pollutant.

2. To study the chemical and physical aspects of atmospheric mercury vapour transformation after polar sunrise and the resultant enhanced Hg^{2+} deposition to the sea, snow and ice surfaces during springtime in the Arctic.

DESCRIPTION

The Arctic ecosystem is exhibiting increasingly disturbing evidence of contamination by a host of persistent, bioaccumulating toxic substances, including heavy metals such as mercury (Jensen *et al.* 1997). Mercury vapour has a residence time of 0.5-2 years in the atmosphere, which renders it susceptible to long range transport and thus a means by which mercury is transported to the Arctic.

In 1995, continuous mercury measurements were started at Alert, Nunavut. Since then, significant advances in our knowledge of atmospheric mercury in the Arctic environment have been made. The discovery of the Arctic springtime depletion of mercury (Schroeder *et al.* 1998) laid the foundation for subsequent important experimental observations regarding the atmospheric transformation and springtime enhanced deposition of mercury in the (Canadian) Arctic. The crucial physical, chemical and photochemical processes responsible for this springtime mercury vapour depletion are not yet known. We currently believe that the rapid oxidation of atmospheric mercury vapour, which occurs in the Arctic after polar sunrise, turns elemental mercury into less volatile forms (particles or reactive) which have much shorter atmospheric lifetime. The relatively rapid deposition to snow or ice of these oxidation products provides an important pathway for the introduction of mercury into the polar biosphere. This phenomenon may impact large areas of the Northern Hemisphere at that time of the year when biota are preparing for their peak summertime activity.

This study is providing scientific data to better understand temporal trends and potential sources of atmospheric total gaseous mercury (TGM) in the high Arctic and to further our knowledge of key atmospheric transformation and deposition processes.

ACTIVITIES IN 1998/99

Ground-based atmospheric TGM was measured continuously at Alert. By the end of 1999, a five-year record of continuous data will have been collected.

Between March and May 1998, we participated in the Polar Sunrise Experiment (PSE'98) to study the springtime mercury depletion phenomenon. Our team collaborated with a number of colleagues from the Atmospheric Environment Service (AES), York University and from U.S. institutions such as Purdue University and the National Center for Atmospheric Research (NCAR). The first "Arctic Mercury Pyrolyser" was employed to investigate the conversion of atmospheric mercury vapour from its long-lived elemental form to oxidized mercury species. In parallel with the pyrolyser experiments, an intensive ambient air sampling campaign for "filterable" particulate-phase mercury species was also carried out.

Additionally, during 1998/99, a number of exploratory tests and preliminary experiments were undertaken to improve existing capabilities for weekly samples of recently fallen Arctic snow.

Experimental results derived from this field study and laboratory work have provided new information and supporting evidence concerning the environmental role of the aerial pathways connecting the atmospheric elemental mercury vapour depletion processes taking place each spring in the Arctic troposphere.

RESULTS AND DISCUSSION

Ground level measurements were continued for TGM in ambient air at Alert. The quality of the data being obtained has improved each year. As a participant in the Canadian Atmospheric Mercury Measurement Network (CAMNet), we now follow the network's QA/QC data protocol in which the Research Data Management and Quality Control System (RDMQ) is used for data processing (Schroeder *et al.* 1999a). Once the data has been thoroughly quality controlled, it will then be submitted to the National Chemistry Database (NatChem). TGM concentrations for 1998 are presented in Figure 1. Similar to previous years, distinct seasonal patterns are observed. These include the perennial springtime mercury vapour depletion phenomenon, and an increase in TGM concentrations in summer followed by a fall decrease to steady background levels. Potential source contribution function modeling results of the 1995 TGM data (Lin *et al.* 1999) indicate that in the fall and winter, anthropogenic contributions include the populated areas in Europe, the United States and Canada. The elevated concentrations in summer appear to be of geological origin, in agreement with previous observations (Xiao *et al.* 1991).

As indicated above, during the PSE'98, the springtime mercury depletion phenomenon was investigated. Previous field studies (Schroeder *et al.* 1999b) revealed a possible anti-correlation between the total particulate mercury (TPM) and TGM during that period. This suggests that the elemental mercury is being converted (by one or more reactive species existing in the springtime Arctic atmosphere) to a more reactive mercury species (likely Hg^{2+}) either in the gas phase or heterogeneously. An Arctic mercury pyrolysis unit was developed and built to confirm and study this conversion.

The pyrolysis unit heats the incoming air to convert all mercury species present in the air to the elemental state (where it can be measured continuously by the analyser). Ambient air was measured in parallel to this pyrolysed air and the difference between the two concentrations was calculated (Table 1). This difference was studied under filtered and unfiltered conditions, where a filter was placed in or removed from the pyrolysis unit to allow (or not) reactive mercury species to enter the heated system. By "reactive mercury species", we mean gas or particle phase oxidation products of elemental mercury.

Results show, under unfiltered conditions, that during a mercury depletion episode, there is a 96% difference between the ambient and pyrolysed air concentrations (Figure 2). However, when the incoming air was filtered, the reactive mercury species were collected before they could be pyrolysed and thus no significant difference (< 5%) was found between the pyrolysed and ambient air concentrations. Similar experiments using the pyrolysis

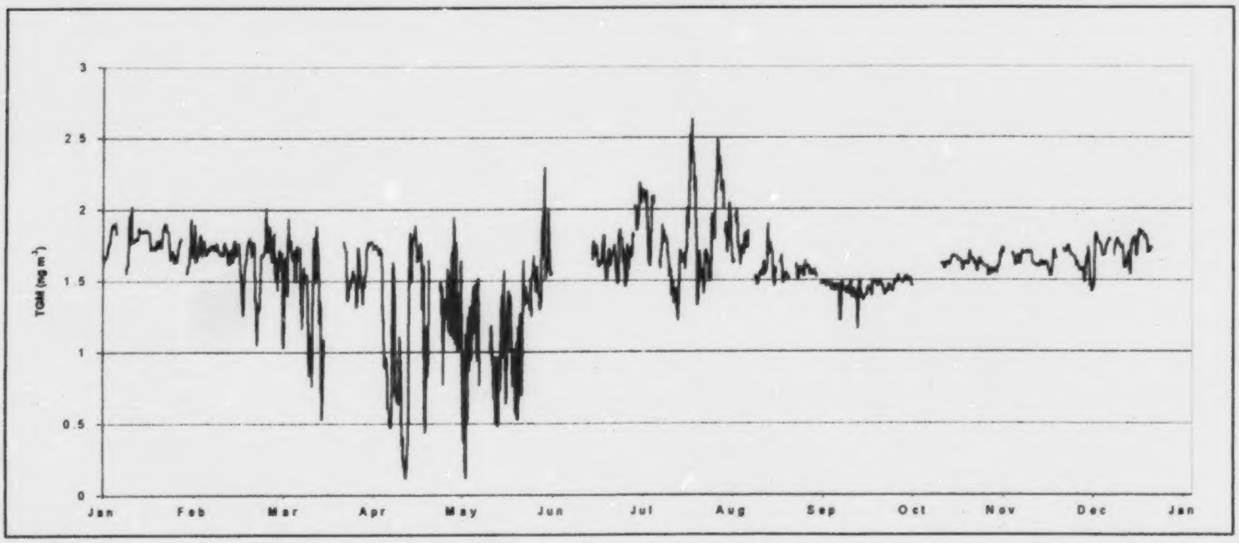

Figure 1. 1998 annual TGM data for Alert (raw data)

Table 1. Percent differences between pyrolysed and ambient air mercury concentrations for PSE 1998.

		Percent Difference (± standard deviation)	
PSE 98	Unfiltered (depletion)	95	*(35)*
PSE 98	Unfiltered (no depletion)	2.2	*(0.5)*
PSE 98	Filtered (depletion)	4.9	*(2.9)*
PSE 98	Filtered (no depletion)	4.4	*(0.8)*
Oct. 98	Filtered (no depletion)	1	*(0.04)*
Oct. 98	Filtered (no depletion)	0.6	*(0.1)*

Note: Depletion is defined as TGM < 1.0 $ng \cdot m^{-3}$

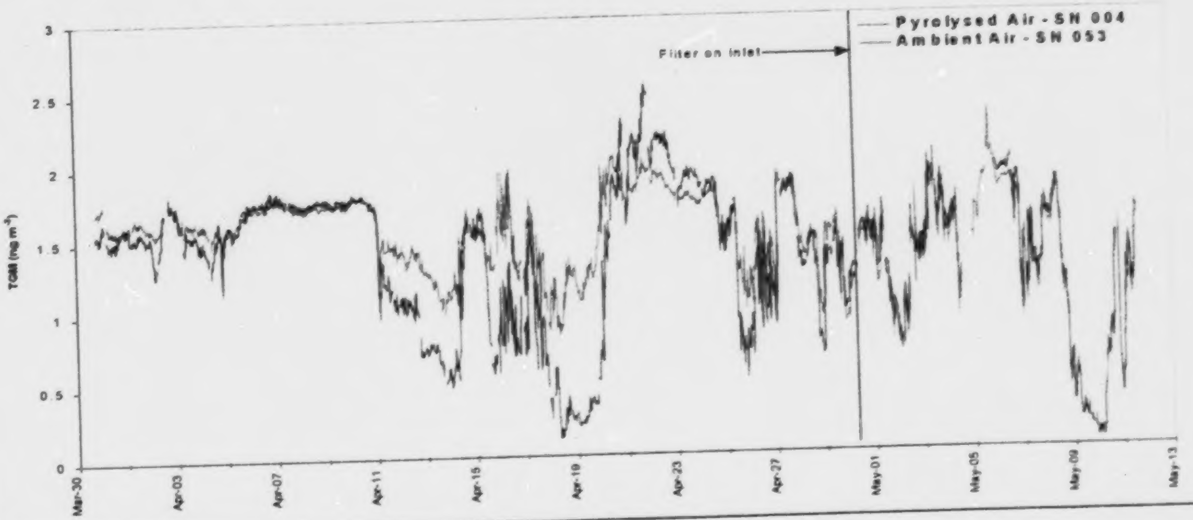

Figure 2. Pyrolysis Unit Results for TPM during PSE 1998 at Alert.

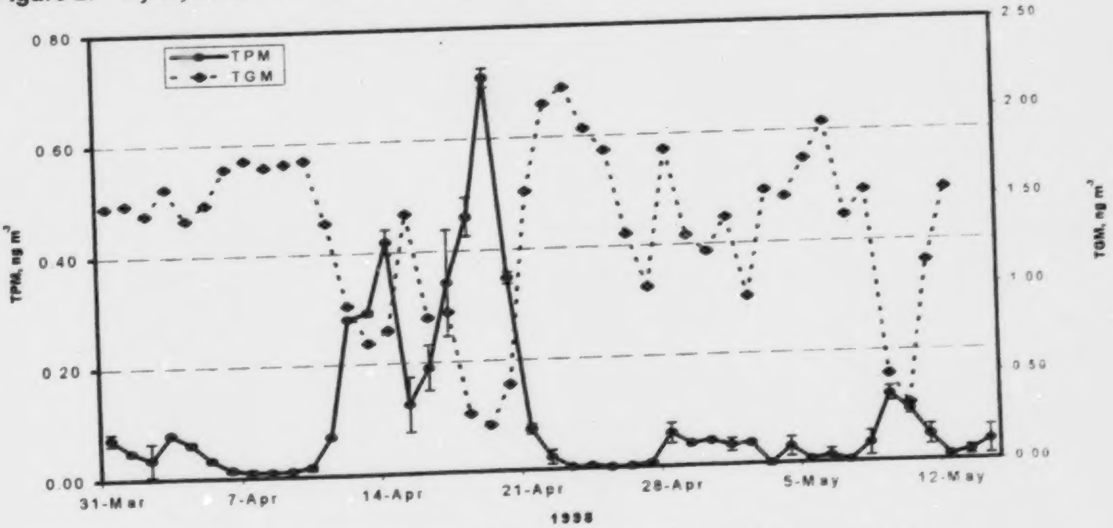

Figure 3. TGM and TPM (AES Technique) Concentrations during PSE 1998 at Alert.

unit were repeated in October 1998. It was found that there was no significant difference (~1%) between the ambient and pyrolysed air (filtered or unfiltered conditions). These results confirm the hypothesis that atmospheric reactive mercury species (gaseous and/or particles) are present during mercury depletion episodes. Several mechanisms of oxidation of elemental mercury to reactive mercury species (likely Hg^{2+}) have been speculated on and include reaction of elemental mercury with BrO, BrCl, Br, Cl, H_2O_2 (Lu *et al.* 1999). Further studies are needed to elucidate the exact nature of the mechanism.

TPM was measured daily during PSE '98 using a sampling and analytical method developed at AES (Lu *et al.* 1998). As indicated above, previous studies have demonstrated a possible anti-correlation between TGM and TPM during depletion events. This was confirmed (Figure 3) during PSE '98, when the TGM concentration decreased, and TPM increased substantially. However, the TPM measured at the baseline observatory at Alert does not account for all the depleted TGM. It has been suggested that the TPM may be deposited to snow en route to Alert (Schroeder *et al.* 1999b). To investigate the atmospheric deposition of mercury to snow, a limited number of freshly fallen snow samples were collected on a Teflon-coated platform during PSE '98. Preliminary results from chemical analyses (G. Lawson 1998, pers. comm.) indicate that there was a significant increase in total mercury concentrations in the snow deposited at those times when atmospheric mercury vapour depletion events had occurred at Alert. For the limited number of samples, mercury levels in the snow increased by 5- to 25-fold as a depletion episode occurred. However, there were insufficient data for a definitive correlation to be established. Thus, a more extensive snow collection survey is required to establish the magnitude and temporal/spatial dimensions of atmospheric deposition fluxes of mercury to the Arctic biosphere during various times of the year.

CONCLUSIONS

Significant advances in the understanding of the role of atmospheric mercury in the Canadian Arctic have been made over the past few years under this program. At the end of this year we will have the first ever five-year continuous Arctic TGM data set. This will help us to understand atmospheric mercury behaviour, temporal trends and potential sources of mercury in the polar regions. For the first time, because of the findings of this research group, various international organizations are preparing to install similar TGM measurement systems in other polar regions (Alaska, Spitzbergen, Greenland). These efforts will lead to a better knowledge of the sources, occurrences and atmospheric fate of mercury in the Arctic environment. This, in turn, will support national and international policies for the effective implementation of environmental protection strategies.

The PSE'98 led the way to further understand the springtime mercury depletion phenomenon. Results from the Arctic pyrolyser experiment show that there is substantial conversion of atmospheric mercury vapour from its long-lived elemental form to one or more oxidized mercury species. Total particulate mercury results demonstrated a negative correlation with TGM as a result of conversion. From preliminary snow sampling results, it was shown that the oxidized species are being deposited to the snow in the springtime. This is of critical importance since these water soluble species are more readily assimilated by Arctic ecosystems and northern wildlife.

Although progress has been made, there are still many questions to be answered about the springtime depletion phenomenon. The actual mechanism of oxidation is still poorly understood. The products of the conversion have not been identified. The impact of the deposition of mercury species to the snow and ice on the ecosystem is still unknown. To try and answer these critical questions, an intensive international experiment "Polar Sunrise 2000" will be conducted in the spring of 2000 at Alert. This collaborative field campaign will provide a unique opportunity to further explore the behaviour of atmospheric mercury along with other key chemical and physical parameters involved in this complex springtime phenomenon.

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INPUTS OF CONTAMINANTS TO THE ARCTIC OCEAN VIA RUSSIAN RIVERS

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Project Team: Derek Muir and Deborah Burniston (NWRI); Valery Surnin and Ludmila Alexeeva, SPA Typhoon (ROSHYDROMET).

OBJECTIVES

Long-term

1. To determine realistic loadings of contaminants (persistent organic pollutants - POPs and trace heavy metals - THMs) in major rivers flowing to the Arctic Ocean and to employ these in budget estimates of Arctic contaminants.

Short-term

2. To obtain information on the concentration, fluxes and data quality of contaminants in Russian rivers in the 1990s.

DESCRIPTION

Recently, data on contaminants in Russian rivers have become available (Alexeeva *et al.* 1997, Zhulidov *et al.* 1998). The sparse reports of metals and trace organic concentrations in the major rivers (Yenesei, Ob and Lena) and a number of others (Pechora, North Dvina, Kola, Piasina, Kolyma) suggested that these sources could collectively pose major inputs to the Arctic Ocean. For example, the model of HCH fluxes in the Arctic Ocean reported in Barrie *et al.* (1997) did not mention total HCHs for "Asian" rivers, although atmospheric and Bering Strait inputs were 66 and 64 tonnes per year. Russian reports of HCH concentration for the Ob plus the Yenesei alone for the early 1990s indicate inputs of 40 tonnes per year. In the case of the THMs, concentration data appear excessively high by North American levels (e.g. Fe total is almost 10^3 tonnes per year all rivers). The AMAP (1998) chapter on POPs (Chapter 3) indicated this data gap – the lack of reliable information on the contaminant contributions from Russian rivers – as a major problem in identifying sources and solutions to the northern contaminants issue.

A major concern about these data is their quality. Laboratories in a total of 10 sub-regions of ROSHYDROMET (Federal System of Russia on Hydrometeorology and the Environment) are involved with both the collection and analysis. These data are collected and analysed according to standard protocols including QA/QC that must be followed. However, the data we are receiving are not exclusively for the mouths of the rivers and there is no information about time of year and/or the river's flow at the time of collection, nor about blanks, detection limits or data treatment. The laboratory at SPA Typhoon has the specific mandate to prepare annual reports on the river "water quality" (including air and soil) data for all of Russia but in the recent past, much of this data has not been processed for lack of resources. The reported methodologies for POPs have detection limits in the low $ng{\cdot}L^{-1}$ level which are 100 times less sensitive than present "western" limits. Determinations of THMs, in Russia as elsewhere in the world, including North America, are highly suspect due to contamination of samples prior to the 1990s and perhaps even later. Data treatment assigns a "zero" value for concentrations less than established limits. Reports examined to date and the loadings based on these reports are averages, which may include these zero values. The reported loadings to the Arctic are also based on average annual flows but the hydrographs of all these rivers have pronounced peaks in May-July. Concentrations and flows should be matched to give more representative loading figures.

ACTIVITIES IN 1998/99

Contracts to gather and assess the available data from river mouths for 1990-1996 (the last year for which the database was complete) were drawn up in April 1999. The THM contract was with Dr. Surnin who is Head of the Department of Environmental Monitoring and Pollution at SPA Typhoon (a part of ROSHYDROMET) in Russia. The contract for the POPs (organochlorine pesticides (OCPs) almost exclusively) was given to Ms. Ludmila Alexeeva, Head of the Pesticide Analytical Laboratory at DEMP/Typhoon. These contracts were iterative between the contractors and sub-contractors at the Hydrochemical Institute of ROSHYDROMET at Rostov-on-Don. This institute has the primary responsibility for quality assurance supervision of the Russian water quality evaluation for surface waters. SPA

Typhoon has an overall role in ROSHYDROMET for evaluating air, water and soil results from several programmes and institutes. Iterative communications also exists between the SPA Typhoon partners and the contract officers at NWRI/Canada Centre for Inland Waters.

The result of these contracts was a joint report from the contractors. The abstract is presented in the sections below.

RESULTS

Information is presented about fluxes and concentrations of OCPs and THMs in water of basins of large Russian rivers flowing to the Arctic Ocean. Some of this information was presented at the International Conference of the Arctic Monitoring and Assessment Program (AMAP) in Tromsø, Norway in June 1997 (Alexeeva *et al.* 1997), and is expanded here with additional data about concentrations of OCPs and THMs for the water at the mouths of selected rivers (or at nearby monitoring stations) and fluxes to the Arctic seas during 1990-1996.

The data are presented as annual concentration means, ranges and sample numbers. These are accompanied by information about locations and conditions of sampling, the methods of analyses and such quality assurance data, as is allowed under Russian law. Development of flux data and comparison of any results – concentrations or fluxes – requires information on the quality of the data and particularly on the reproducibility of each mean or average value being compared. The level of detail of such information provided is not sufficient to distinguish whether differences in annual values are significant, although some generic indications of this can be found in the report. Analytical methods are improving but are still insensitive according to detection limits of methods in use elsewhere.

Data on the fluxes to the several Russian Northern Seas for contaminants with more complete databases are presented in Table 1. It is noted that fluxes in the report pertain to a total of 15 rivers, which are the largest in the Russian north. However, these fluxes are minima as not all of the rivers are represented. It is also observed that the concentration data (and therefore the fluxes) for the more easterly rivers (those of the Laptev and East Siberian Seas) are few and almost universally zero for the OCPs. Data for mercury and lead are given but they pertain only to a limited part of the region and for short periods of time.

DISCUSSION

During the contract period, a report appeared in the western press on contaminant levels from some of the same rivers and time periods as are presented in this contract report (Zhulidov *et al.* 1998). The press report compared results from the ROSHYDROMET initiative (as in this report) and from an independent sampling and analysis effort. The comparisons indicated that levels reported by ROSHYDROMET were higher than those of the consultants although this is done using the number of exceedances rather than "absolute" values. Comparisons are also difficult because only ranges are presented. Which values are correct is therefore uncertain but it does indicate a need for closer examination of the data generation.

It is not easy to comment confidently on data which have such varied sources. These data come from six regional laboratories, several of which have "sub-laboratories", covering 15 rivers draining most of geographic Russia (all those rivers draining into the Arctic Ocean). Occasional extreme values were pointed out to the sub-contractors; on most occasions, it turned out that there was a problem with the data point in question and that point was removed. Russian law does not permit the release of individual data points so that the data are presented as annual means for individual rivers along with ranges and number of samples. Standard deviations or other error estimates were not available. The final concentration mean values in the report are high relative to those observed from the North American Rivers, as are the detection levels. When a result of "<DL" (less than detection level) occurs, a zero value is used in evaluating the annual mean. This necessarily biases the mean value low. The fluxes, determined from these means, must be assumed to be minimal.

Table 1. Average Annual Fluxes ($x10^3$ tonnes per year, 1990-1996)

	White/Barents Seas	Kara Sea	Laptev Sea	E. Siberian Sea
Fe	134	676	32	143
Cu	1	8	2	0.8
Zn	5	34	6	1
α-HCH	0.5	15.	?	0.2
γ-HCH	2	26.	0.5	0.2

An additional "benefit" occurred during the course of this contract/project. The contractors provided a large amount of data on pesticide usage and soil concentrations throughout Russia and information about the current status of all pesticides, including registration and use.

There were also numerous data from prior to 1990 but which have not been evaluated. Not surprising-ly, the concentration levels from the data are even higher than those from the study period. Also received were generic descriptions of the watersheds of the study rivers and summaries of the possible anthropogenic and geological factors that may be contributing to the levels in the river.

The contract officers have the data in electronic form as well as hard copy. The Northern Contaminants Program has been provided with hard copies. Enquires are welcomed and a publication is planned.

Project Completion Date: March 31, 1999

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ORGANOCHLORINE AND PEROXYACETYL CONTAMINANTS IN ARCTIC ARCHIPELAGO AIR AND WATERS

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Project Team: Camilla Teixeira, NWRI; Aaron Fisk, Lyle Lockhart, and Gary Stern, Freshwater Institute (FWI); Ross Norstrom, Canadian Wildlife Service; Terry Bidleman, Atmospheric Environment Service

OBJECTIVES

Long-term

1. To provide data for and assess the bioaccumulation of POPs in food webs in the Arctic Archipelago and to evaluate the fluxes of contaminants through the Canadian Archipelago in an overall mass budget assessment of the Arctic Ocean.

Short-term

2. To collect and analyse water, air and sediment samples for persistent organic pollutants (POPs) during the passage of the Canadian Coast Guard Ship (CCGS) icebreaker *Louis S. St. Laurent* through the Northwest Passage (Joint Oceanographic and Ice Studies - JOIS) during 1997 and 1998.

DESCRIPTION

Control of POPs contaminants within the Arctic (e.g. United Nations Economic Commission for Europe (UN-ECE) Convention on Long-range Transboundary Air Pollution (LRTAP) POPs Protocols) rests on persuading governments outside the Arctic region of the importance of limiting the use of POPs within their jurisdictions. This, in turn, depends on presenting a case which demonstrates that the release of POPs in these countries is influencing levels of POPs in the Arctic region, and that these levels will be lowered by controls on the use of POPs. Such a case relies upon on a solid database on the present contaminant levels in the Arctic ecosystem and on spatial and temporal trends developed using past and present data. The Northern Contaminants Program (NCP) workshop in Iqaluit (July 1997) indicated a need to focus on bioaccumulation of POPs in traditional foods in the region. However, contaminant concentrations in water, air and sediments are also needed to model and quantify exposures in the Arctic and to project temporal trends in contaminant concentrations in traditional food following the implementation of national and international control measures.

All bioaccumulation/biomagnification expressions in models ultimately must include a term for contaminant concentration in water. While some recent data exist for concentrations of POPs contaminants in the Arctic Ocean (Strachan *et al.* 1998, Barrie *et al.* 1997, Science of Total Environment 1995), the data for the Canadian Archipelago, which is the major surface water output from the Arctic Ocean (Barrie *et al.* 1997), is limited. Some work on the water and air of the region has been done at Resolute Bay (Bidleman *et al.* 1995) and for air at Alert and Cape Dorset (summary in the Canadian Arctic Contaminants Assessment Report (CACAR); Jensen *et al.* 1997) but there have been no widespread assessments. Most emphasis has been on the relatively abundant HCHs with toxaphene being the subject of limited additional investigation. Other organochlorines have received much less attention.

In 1997, the Department of Fisheries and Oceans (DFO) and the US National Science Foundation (NSF) initiated the surface heat budget of the Arctic (SHEBA) study in which a Canadian icebreaker, CCGS *Des Groseilliers*, was installed in the permanent icecap along the Canada-U.S. border at 75-76°N. Supply ships to the icebreaker passed through the Canadian Archipelago as part of the commissioning and decommissioning of the SHEBA initiative. The use of these vessels as sampling platforms was offered by DFO. This opportunity, the 1997 JOIS-I expedition, provided for the first part of this project. Reports on that data development were made last year.

ACTIVITIES IN 1998/99

In the 1998/99 fiscal year, support was allocated to cover the collection and partial analytical costs of samples. This collection was to take place during the 1998 decommissioning expedition (JOIS-II) for the SHEBA expedition. However, shipboard space proved unavailable for this part of the expedition. Active participation was therefore precluded and alternatives for sampling in the region were sought.

Prior to CCGS *Des Groseilliers* "breaking out" from the icecap of the Canada Basin, CCGS *Louis S. St. Laurent* was involved with the Northwater (NOW) project in the eastern Archipelago and Baffin Bay regions. The opportunity was made available to collect samples during this expedition. As a consequence, samples were collected for the stated purposes of the project using the facilities of the NOW project. Surface water samples were collected from the northern parts of Baffin Bay in three transects between Baffin Island and Greenland during May 1998. A total of 30 water samples were obtained from depths of roughly 2 m (19 samples) and other depths from 20-500 m (10 samples). These water samples were of two types: whole water samples (approximately 75 L) which were obtained from separate casts of a 100 L Go-Flo bottle from depths other than the surface; and similarly sized duplicate samples pumped on board from surface water sites. Analyte extraction was done by pumping the water sample through approximately 75 g XAD-2 resin and refrigeration of the capped resin columns. All further processing of the samples took place at the NWRI laboratories according to standard procedures.

The POP analytes investigated included organochlorine pesticides (20), PCBs (132 congeners including18 coelutants plus total), chlorobenzenes (9) and PAHs (18 priority pollutants). All have been desorbed from the XAD2 resin and have been "cleaned-up" and fractionated on silica gel and are ready for GC analysis and subsequent data evaluation. The sample analyses are expected to be completed in 1999.

Expected Project Completion Date: December 31, 1999.

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GLOBAL MODELLING OF POLYCHLORINATED BIPHENYLS

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Project Team: Don Mackay, Trent University, Peterborough; Michael McLachlan, Institute for Baltic Sea Research, Warnemünde, Germany; Andrew Sweetman and Kevin Jones, Lancaster University, Lancaster, U.K.

OBJECTIVES

The main objective of the project is to describe quantitatively with model calculations the global distribution behaviour of persistent organic contaminants. Specifically:

1. To incorporate a forest canopy compartment in the zonally averaged global distribution model, to test whether the boreal forests act as efficient filters for semi-volatile organic compounds during the atmospheric transport to the North; and
2. To conduct a comprehensive study of the global fate of polychlorinated biphenyls (PCBs) using the zonally averaged global distribution model, with a particular focus on changes in the relative homologue composition with latitude and between different compartments.

DESCRIPTION

Substantial interest in the long-term behaviour and final fate of persistent organic pollutants (POPs) arises from the continued presence of such substances in the global environment. Although many were banned or restricted decades ago, they continue to be detected at considerable levels in the environment, even far from their points of initial release (Wania 1999). By providing only snapshots of the overall situation in space and time, measurements alone can not hope to elucidate the full complexity of POP fate in the global multi-compartment environment. A zonally averaged global distribution model has previously been shown to reveal many facets of the global behaviour of α-hexachlorocyclohexane (α-HCH) (Wania *et al.* 1999) over the five decades of its large scale environmental release, including the capability for simple pathway analysis, source apportionment and trend prediction (Wania and Mackay 1999). The aim of the present study is to conduct a similar comprehensive study of the global historical fate of polychlorinated biphenyls (PCBs) using this global distribution model, with a particular focus on changes in the relative congeneric composition with latitude and between different compartments. Final outcome will be a quantitative demonstration of the extent and mechanisms of the poleward migration of PCBs.

ACTIVITIES IN 1998/99

Activity 1: Incorporating a forest canopy compartment in the global distribution model

In a paper on the enhanced deposition of some semi-volatile organic compounds to forest canopies, McLachlan and Horstmann (1998) concluded that "while forests are certain to play an important role in the fate of semivolatile organic compounds at all latitudes, the boreal forests of the northern hemisphere could be a particularly important filter for compounds moving north that are still gaseous at these latitudes but which condense onto particles and be deposited in the colder polar air." To account for this effect and to assess its magnitude, a forest canopy module for fugacity-based multi-media mass balance models has been developed and incorporated into the existing zonally averaged global distribution model. A detailed account of the technical details, namely the description of equilibrium partitioning into the canopy compartment, as well as the kinetics of the chemical transfer processes between the atmosphere, the canopy and the forest soil is given elsewhere (Wania and McLachlan 1999).

The model with the additional forest compartments was used to repeat the previous calculations with α-HCHs (Wania *et al.* 1999), revealing no significant effect of this change in model structure on the calculated global fate of α-HCH (Wania *et al.* 1998). Closer analysis indicates that this lack of an effect is due to the particular physical-chemical properties of α-HCH. The inclusion of a forest canopy compartment does, however, significantly change the modeled fate of less water soluble and less volatile substances such as the PCBs. Specifically, it was observed that: (1) the addition of a forest compartment in some cases decreased PCB concentrations in air and water by more than a factor of two; and (2) for selected PCB isomers, concentrations in forest soils exceeded those in agricultural soils by more than a factor of 5, which could be explained by the reduced ability of the chemical to re-evaporate from forest soils after deposition with litter fall. The ability of the model to reproduce the forest filter effect as observed in field measurements was confirmed. A manuscript on modeling the role of forests in the overall chemical fate of POPs is presently in preparation (Wania and McLachlan 1999).

Activity 2: Model modification and input data collection

The global distribution model is a fugacity-based mass balance model that describes the global environment through 10 latitudinal bands (or climate zones), each of which is divided into a set of well-mixed compartments, representing environmental phases such as the atmosphere, the terrestrial, the freshwater and the marine environments. Provided with historical emission estimates on a global scale, it calculates fugacities, amounts and concentrations in each of these compartments and chemical fluxes between them. A detailed description of the model can be found in Wania and Mackay (1995) and Wania *et al.* (1999). In order to simulate the global fate of PCBs with this model, further model modifications and a global historical emission estimate were required, and it was necessary to compile a consistent set of chemical input parameters for selected PCB congeners.

Model Modification

Several improvements and modifications have been made to the model compared to the version used for the α-HCH simulation (Wania *et al.* 1999). Briefly, these are:

- The diffusion distance in agricultural soil is no longer a fixed fraction of the soil depth, but a time-variable function of the soil-air partition coefficient. This accounts for the large capacity of the surface soil micro-layer for hydrophobic substances such as PCBs, which often eliminates the need of these chemicals to diffuse through the bulk soil to the soil surface (McLachlan and Wania 1999).
- Atmospheric hydroxyl radical concentrations in the model are based on a two- dimensional (i.e. zonally averaged) distribution of OH radicals in the global atmosphere calculated by Rodriguez *et al.* (1992).
- The particle settling rate on the oceans has been reduced by an order of magnitude. An earlier exercise which used the global model as a predictive tool to identify the physical-chemical properties that make chemicals susceptible to long range transport to Arctic regions (Wania 1998) had revealed that the model overestimates the transfer of particle-sorptive chemicals from the surface ocean to the deep sea.
- Due to the lack of measured Henry's Law constants (HLC) of PCBs in seawater, no distinction is made between the HLC in fresh water and sea water.
- The calculation of gas-particle partitioning is based on a K_{OA}-relationship presented by Finizio *et al.* (1997) and no longer on the classical Junge-Pankow relationship using vapour pressure P_L. This modification eliminates the need to specify P_L.
- The calculation of the degradation rate in media other than the atmosphere is based on a degradation rate at a reference temperature 25°C and an activation energy.

Global Emission Estimates for PCBs

An estimate of the historical emissions of the seven most commonly measured PCB isomers (28, 52, 101, 118, 153, 138, and 180) into the global environment from 1930 to 1994 was supplied for five-year periods by Sweetman and Jones (pers. comm.). The data are based on production records in the following countries: U.K., Germany, Italy, France, Spain, U.S.A., Japan, Australia, New Zealand, and the former U.S.S.R. Different use categories, such as large capacitors, small capacitors and open uses (plasticiser, petroleum additives, etc.) and their different release characteristics were taken into account. The assignment of the country-specific release records to the ten climatic zones used in the model revealed that only releases into the Northern temperate and subtropical region, estimated at 48 kt and 11 kt respectively, seem to be of global significance. The congeneric composition of these emissions (see Table 1) was assumed to be: (1) constant throughout the emission period; and (2) identical in the temperate and subtropical zones. All release was assumed to occur into the atmosphere. The data for the five-year periods reported by Sweetman and Jones (pers.comm.) were distributed into annual emission rates, and extrapolated until the year 2000 (Figure 1). The temporal profile of the estimated emissions has a triangular shape, suggesting a peak release in the early 1970s with a linear increase before and a linear decrease after that date.

Chemical Input Data for PCB Congeners

When modeling a group of related substances, such as several PCB congeners, it is imperative to a have a consistent set of chemical property data (physical-chemical properties and degradation half-lives). This is necessary for a meaningful prediction and analysis of congeneric composition. The three required physical-chemical property data, i.e. molecular mass, octanol-water partition coefficient and the temperature dependent Henry's Law constant were taken from a recent compilation by Paasivirta *et al.* (1999). The previous calculations for α-HCH (Wania *et al.* 1999) had revealed the immense importance of degradation processes on the global fate of POPs, but also the considerable uncertainty and variability associated with the selection of degradation rates. In the case of the PCBs, this issue is further complicated by the variable persistences of the different congeners. Based on a

Table 1. Relative composition (from Sweetman and Jones, pers. comm.), physical-chemical properties (from Paasivirta et al. 1999), degradation rates with OH radicals in the vapour phase k_{OH} and degradation half-lives (HL) for the seven PCB congeners used in the global model simulations.

Congener	Structure	w.% of Σ_7PCB	MW g·mol^{-1}	log K_{OW}	log H Pa m^3·mol^{-1}	k_{OH} cm^3/(molecules·s)	HL_{canopy} hours	HL_{soil} hours	HL_{water} hours	$HL_{sediment}$ hours
PCB-28	2,4,4'-triCB	18.1	257.5	5.67	11.97 - 3100 / T	$1.04 \cdot 10^{-12}$	5500	10000	5500	17000
PCB-52	2,2',5,5'-tetraCB	19.0	292	6.10	13.15 - 3352 / T	$0.59 \cdot 10^{-12}$	10000	17000	10000	55000
PCB-101	2,2'4,5,5'-pentaCB	18.6	326.4	6.37	13.55 - 3531 / T	$0.30 \cdot 10^{-12}$	31000	100000	31000	55000
PCB-118	2,3'4,4',5-pentaCB	14.3	326.4	6.60	13.44 - 3535 / T	$0.30 \cdot 10^{-12}$	31000	100000	31000	55000
PCB-138	2,2',3,4,4',5'-hexaCB	14.9	360.9	6.65	13.93 - 3757 / T	$0.16 \cdot 10^{-12}$	55000	170000	55000	170000
PCB-153	2,2',4,4',5,5'-hexaCB	10.0	360.9	6.88	14.05 - 3662 / T	$0.16 \cdot 10^{-12}$	55000	550000	55000	170000
PCB-180	2,2'3,4,4',5,5'-heptaCB	5.2	395.3	7.20	14.71 - 3910 / T	$0.10 \cdot 10^{-12}$	55000	1000000	55000	170000

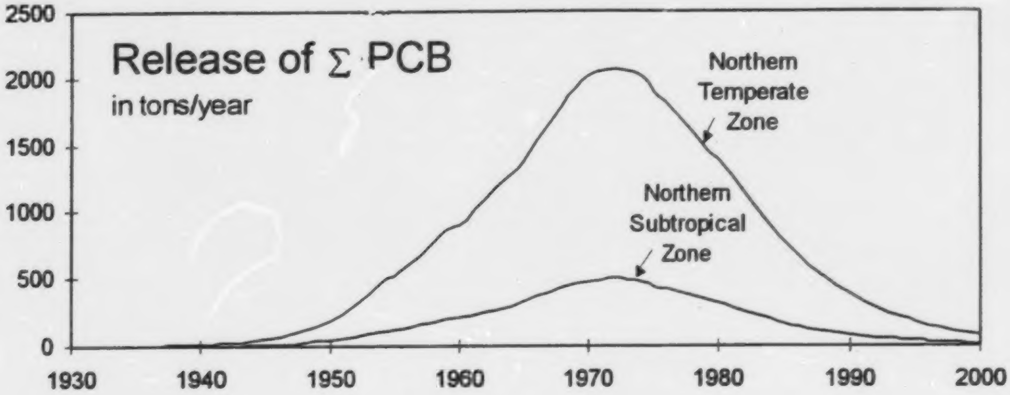

Figure 1. Estimated release of the sum of seven PCB isomers into the global environment (from Sweetman and Jones, pers. comm.). The total amount emitted between 1930 and 1994 was 48.1 kt into the Northern temperate zone and 11.1 kt in the Northern subtropical zone.

correlation by Atkinson (1996), gas-phase reaction rate constants of the selected PCB congeners with OH radicals at 25°C were estimated. In the model, these rates are combined with spatially and temporally variable atmospheric temperatures and OH radical concentrations to calculate a time-dependent degradation rate. Similar sets of degradation rates (or rather half-lives) were derived for the other model compartments (water, soils and sediments) from the published literature, giving more emphasis on field-based studies than on laboratory derived half-lives. Degree of chlorination as well as substitution pattern were taken into account. No distinction was made between degradation in fresh water and sea water, or between degradation in agricultural and forest soils. Due to the lack of better information, the degradation half-life in the forest canopy compartment was assumed to be the same as in water. The selected data are given in Table 1. Activation energies between 10 and 30 kJ·mol^{-1} were assumed to apply.

Activity 3: Conducting global model simulation of PCBs

The modified model, the global emission estimates and the chemical input data were used to perform a simulation of the global fate of seven PCB congeners between 1930 and 2000.

RESULTS

Whereas only a glimpse of the simulation results for PCBs in the global environment can be presented here, more detail can be found in a report (Wania 1999b). The simulation results should also be considered preliminary. In particular, no thorough attempt to compare the results with observations has so far been undertaken.

Absolute Levels and Time Trends in Various Compartments

Figure 2 shows the concentrations calculated for the sum of seven PCB isomers (Σ_7PCB) in the atmospheric boundary layer, seawater, agricultural soils and forest foliage. Several aspects of these curves can be interpreted, namely the absolute levels, the zonal differences and the time trends.

Absolute levels in the various compartments

Calculated average air concentrations of Σ_7PCB during the peak emission period were 250 to 500 pg·m^{-3} in the zones experiencing emissions. In the 1990s, levels have fallen below 100 pg·m^{-3}. For the marine environment the model calculates zonally averaged Σ_7PCB concentrations in the range 20 to 130 pg·L^{-1} during the 1970s (up to 300 pg·L^{-1} in the temperate zone), and below 50 pg·L^{-1} in the 1990s. Σ_7PCB concentrations calculated for agricultural soils and foliage are in the range of 0.3 to 1.1 ng·g^{-1} and 5 to 50 ng·g^{-1}, respectively, but somewhat lower in the tropics. A preliminary comparison of these values with measurements in the global environment, e.g. those compiled by Axelman and Broman (1997), suggests that they are in the correct order of magnitude. When interpreting these data, it is imperative to keep in mind the zonal averaging characteristics of the model. The emission estimates suggest that most of the countries emitting substantial amounts of PCBs were and are in Europe and North America, yet there are large regions within the temperate and subtropical zones, particularly in Asia, which experienced much lower PCB emissions. Most measurements of PCBs in the environment were

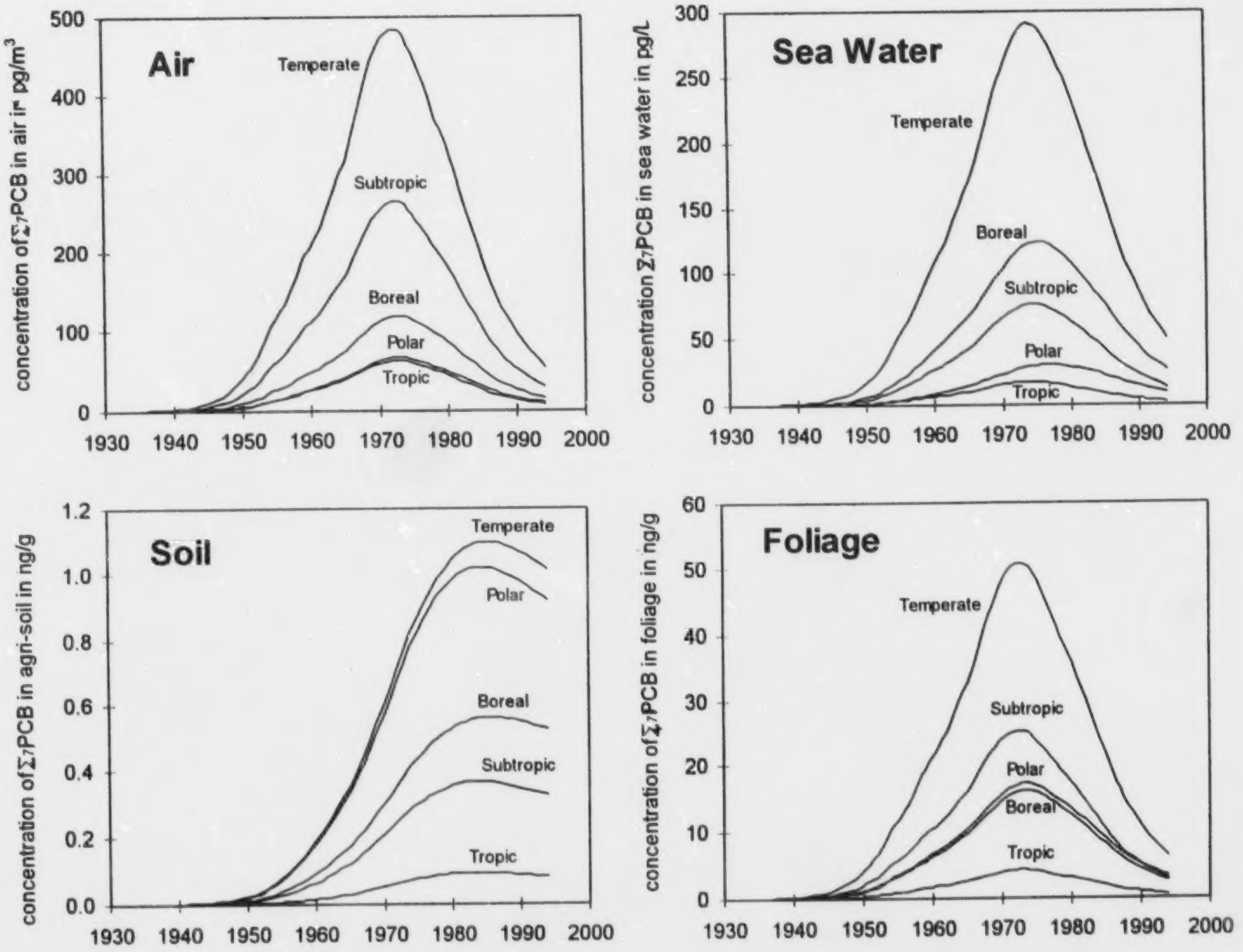

Figure 2. Σ_7PCB concentrations in four compartments (lower atmosphere, seawater, agricultural soil and forest foliage) in the five zones of the Northern Hemisphere.

conducted in emission regions and are thus likely too high when compared with zonally averaged simulation results.

Relative levels in the various zones

The highest levels are calculated for the Northern temperate zone, but ocean and soil environments show relatively high levels in the two northernmost zones. The boreal zone has higher seawater concentrations than the subtropical zone, and soil concentrations in the polar and boreal zone are higher than those in the subtropical zone.

Time delay

Compartments differ in the immediacy of their response towards emission changes. Emissions peaked in 1972, and so do the calculated air concentrations. Foliage concentrations lag only by about one to two years, whereas seawater concentrations lag by two to five years, with the delay increasing with latitude. The model suggests that soils are particularly slow to respond to the decrease in PCB emissions during the last three decades. Peak concentrations in soil are calculated for the mid-1980s, i.e. a delay of more than a decade, and the decrease since then has been slow.

Overall Cumulative Fate of PCBs

The model simulation suggests that of the total amount of Σ_7PCB released between 1930 and 2000, 64% have been degraded, 18% have been transferred to the deep sea and 1% has been buried in freshwater sediments. Seventeen percent of what has been emitted is still dispersed in the global environment today. However, the fate of the seven PCB congeners differs considerably in this respect (Figure 3). The model suggests that most of the lighter PCBs, such as PCB-28 and -52 have been degraded, and less than 1% of the cumulative emission is still in the environment today. The relative importance of degradation as a loss process rapidly decreases with increasing degree of chlorination, and deep sea transfer becomes a more important final loss process. A considerable fraction of the heavier congeners, such as PCB-153 and -180 is still dispersed in the environment today. From a global perspective, freshwater sediment burial does not appear to be significant for any of the PCB congeners. The congeners not only differ in the extent of loss by degradation, but also in terms of where the degradation took place. For the smaller congeners, the atmosphere is the primary medium of degradation, whereas for the higher chlorinated congeners the seawater environment is more important. The intermediate PCBs are degraded to a large extent in soils.

Congeneric Composition in Various Compartments and Zones

One of the main objectives of this modeling exercise is to investigate the compositional shifts that occur within the PCB profile along latitudinal and temporal gradients. Figure 4 shows the congeneric composition (i.e. percent of Σ_7PCB) as calculated by the model for selected compartments of the tropical, temperate and polar zone of the Northern hemisphere in 1994. For comparison, such profiles for the PCB emissions and for the total inventory of PCBs in the global environment in 1994 are included. The profiles are very different in various compartments of the same climate zone and also in the same compartments of various climate zones. This reflects the variable environmental fate of PCB congeners, which differ by less than two orders of magnitude in K_{ow}, HLC and degradation half-lives (Table 1).

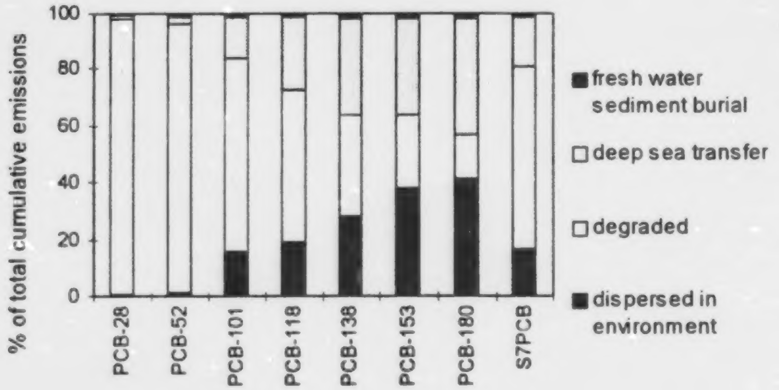

Figure 3. Calculated percentage of the total accumulated emission of each PCB congener and Σ_7PCB, which has been degraded, transferred to the deep sea, buried in freshwater sediments, or is still dispersed in the global environment in 2000.

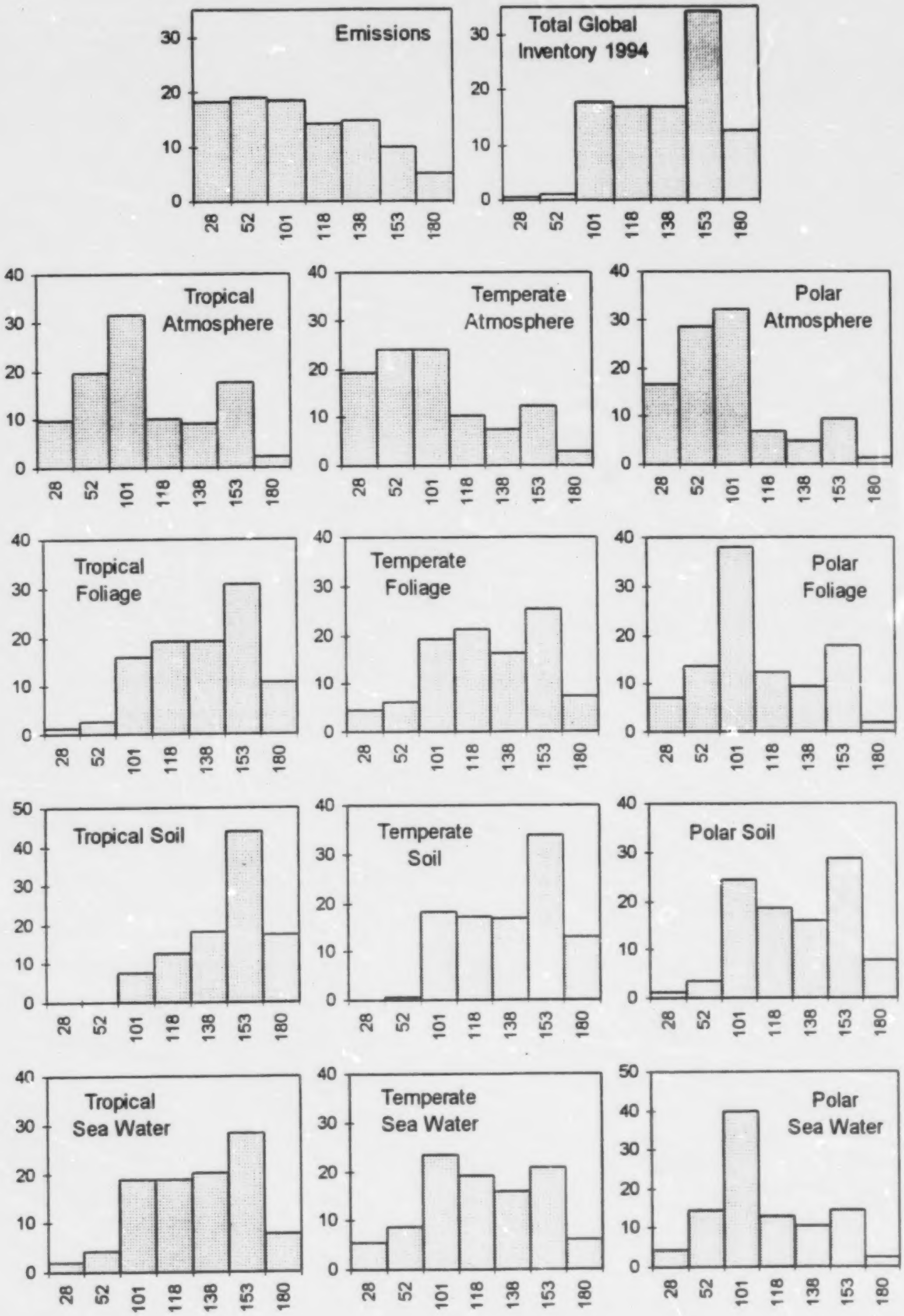

Figure 4. Calculated congeneric composition (percent of Σ_7PCB) of the PCB emissions, of the total global environmental inventory, and of the PCBs found in four different compartments in three different zones in 1994.

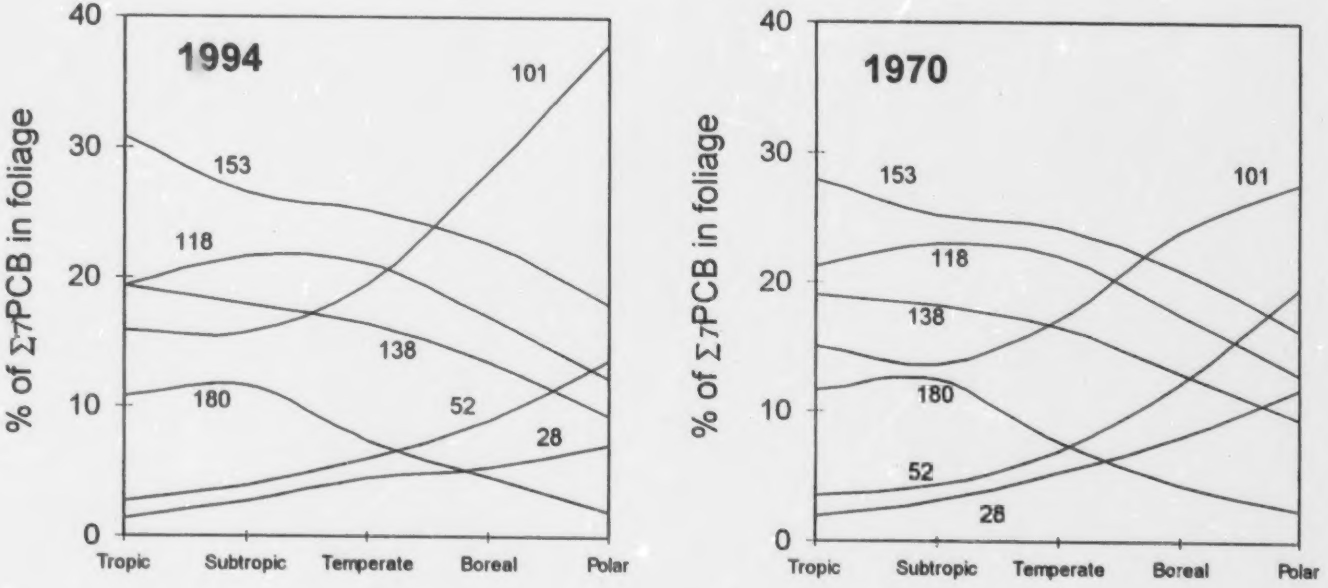

Figure 5. Calculated congeneric composition of PCRs on foliage as a function of latitude in 1994 and 1970.

The calculated atmospheric profiles are dominated by the three lighter PCB congeners and resemble most closely the emission profile, especially in the temperate zone. In the tropical atmosphere, the two smallest congeners are relatively depleted, probably because of fast loss by degradation. In the polar atmosphere, on the other hand, the heavy congeners are underrepresented, presumably due to a reduced long range transport potential of these less volatile constituents. The foliage profiles are dominated by the intermediate PCB congeners with five and six chlorine substitutions. This may be a result of the uptake of the lighter PCBs being limited by the capacity of the foliage, and that of heavy congeners being kinetically limited. There is also a clear shift towards lighter congeners with increasing latitude (see also below). The soil profiles (especially in the temperate zone) resemble most closely that of the total inventory in 1994. This is not surprising, considering that the soils of the temperate zone are the major environmental reservoir for PCBs in 1994. These profiles are depleted in PCB-28 and PCB-52 and enriched in PCB-153 and to a lesser extent also PCB-180. Finally, the seawater profiles are dominated again by the penta- and hexachlorinated congeners. Congeners with less than five chlorine substitutions may be lost by degradation in the aqueous environment, and those with more than seven chlorine atoms by particle mediated transfer to the deep sea.

Figure 5 shows the composition of PCBs on foliage as a function of latitude. A shift to the more volatile congeners at higher latitudes is obvious. The fractions of 28, 52 and 101 increase sharply with latitude, whereas those of 118, 138, 153 and 180 decrease. This closely reproduces the compositional changes reported for PCBs in semipermeable membrane devices (SPMDs) exposed along a latitudinal band from 50-70°N along the European west coast during the 1990s (Ockenden *et al.* 1998; Figure 5a). The SPMDs, which in many respects can be seen as "standardised foliage", also showed a strong increase of the lighter PCBs, in particular the tetrachlorinated congeners with increasing latitude, at the expense of hexa- and heptachlorinated congeners.

The congeneric composition of PCBs in various environmental phases differs (Figure 4). Accordingly, shifts in the congeneric composition with latitude and in time are also different in different phases. Generally, however, all phases demonstrate the shift from lower to higher congeners with increasing latitude. A comparison of the profiles for 1970 and 1994 suggests that whereas overall changes have been minor, the fractionation effect has been increasing with time. The relative fraction of PCB-28 and PCB-52 decreased in all zones and media as a result of their rapid degradation.

CONCLUSIONS

The following conclusions can be drawn:

- The model is capable of describing the fate of PCBs in a long-term perspective, and in particular can be used to investigate compositional shifts among the PCB congeners between compartments, zones and different time periods.
- A preliminary evaluation suggests reasonable agreement between model results and measurements, but more detailed analysis is required.
- The simulated fate of the various PCB congeners differs greatly, reaffirming the need to perform calculations for individual chemicals rather than for hypothetical chemicals with averaged property values.
- The final destiny of PCBs in the global environment is degradation and transfer to the deep sea. The former is of primary importance to the lighter congeners, and the latter increases in importance with the degree of chlorination. Burial in freshwater sediments is of little significance on a global scale, but may be important locally.
- The model results reproduce shifts towards lighter PCB congeners with increasing latitude, as have been predicted by the global fractionation hypothesis and as have been observed in various monitoring programs.
- The model further suggests that elevated PCB concentration levels in the Arctic can be explained by relatively minor fractions of the global inventory of PCBs being transferred northward (the model calculates that between 1% (PCB-180) and 9% (PCB-28) of the total global inventory of a PCB congener is present in the Arctic zone in 1994). This has already been found to apply to α-HCH.
- According to the model, close to 1 kt of PCBs has been net transferred to the Arctic within the past 70 years. The atmosphere is the major vehicle for meridional transport of PCBs to the Arctic. Oceanic net transport rates tend to be lower than atmospheric net transport by an order of magnitude.

Future efforts will be focussed on: (1) the revision of environmental input parameters (in particular the particle settling rates in the oceans); (2) the revision of chemical input parameters (specifically accounting for the salinity effect on HLCs and improving the selection of degradation half-lives and their temperature dependence); (3) a sensitivity and uncertainty analysis; and (4) a thorough model evaluation. The latter will focus on the capability of the model to reproduce: (i) measured absolute concentration levels and fluxes; (ii) measured congeneric compositions; and (iii) time trends in concentrations and compositions. Eventually, the model will be used for tasks involving pathway analysis, source apportionment and trend predictions.

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MERCURY ACCUMULATION IN SNOW ON SEA ICE

Project Leaders: Harold Welch, Winnipeg, MB; Kathleen Martin, Lyle Lockhart, and Gail Boila, Department of Fisheries and Oceans, Winnipeg, MB

Project Team: On-site cooperators, often the staff and students at high schools in Arctic coastal communities

OBJECTIVES

1. To determine the amount and regional distribution of mercury coming into the Canadian Arctic and sub-Arctic via long-range atmospheric transport and accumulating in snow over sea ice during winter.

DESCRIPTION

Mercury levels in fish and marine mammals throughout the Canadian North often exceed levels set to protect the health of people consuming them (Jensen *et al.* 1997). Anthropogenic sources have increased the concentrations of mercury in air and seas of the Northern Hemisphere (Mason *et al.* 1994, Fitzgerald 1995) and there is evidence that inputs of mercury to the Arctic have increased. For example, sediments of arctic lakes have apparent record increases during the 1900s (Lockhart *et al.* 1995, 1998). Mercury levels in arctic seals and beluga whales have increased over the past two decades (Wagemann *et al.* 1996, Hyatt *et al.* 1999). Similarly, mercury levels in arctic sea birds have also increased (Braune, pers. comm. 1999). There are also indications that inputs to humans have increased; mercury levels in hair and sealskin clothing of Greenlanders from several hundred years ago were compared with modern samples and the latter were several times higher.

Atmospheric transport is the most important pathway for the transport of mercury into the Arctic (Pacyna and Keeler 1995), but there is currently little information on the actual quantity being deposited across the Canadian Arctic Ocean. We have estimates of anthropogenic fluxes to lake sediments and some to Hudson Bay (Lockhart *et al.* 1998) but we have no direct measurements to calculate fluxes to the Arctic Ocean.

It is likely that most atmospheric mercury transport and deposition occurs during winter, especially in March-May. Therefore it is reasonable to expect that by quantifying the amount of mercury in the snow cover on sea ice just before melt, we can get an estimate of the minimum annual quantities and distributions of mercury entering the Arctic. Note that we have included only sites over sea ice since we do not wish to get into terrestrial sites where there will be debate about whether mercury in the snow came from the atmosphere or from the soil. The success of the first year of this study (see Welch *et al.* 1999) prompted the continuation of the project for 1998.

ACTIVITIES IN 1998/99

Snow samples were obtained from the following communities in the Spring of 1998: Pelly Bay, Baker Lake, Tasiujaq, Taloyoak, Cambridge Bay, Sanikiluaq, Whale Cove, Clyde River, Resolute, Kimmirut, Gjoa Haven, Arctic Bay, Iqaluit and Grise Fiord. A number of additional communities participated in the project but the early spring melt in 1998 precluded the collection of samples for safety reasons.

RESULTS

The mercury concentrations in meltwater from the snow samples taken in 1998 are listed in Table 1 and shown in the map in Figure 1. Comparable results from 1997 were reported by Welch *et al.* (1999), as were the individual event collections taken in the Beaufort Sea. Generally the values in 1998 varied from site to site, with means similar to those obtained in 1997 (Table 2). Mean meltwater mercury was 45.5 $ng{\cdot}L^{-1}$ in 1997 as compared with 40.5 $ng{\cdot}L^{-1}$ in 1998.

The purpose of obtaining the snow samples originally was to estimate the loading of mercury to the Arctic Ocean. This calculation has been made by Lu *et al.* (1999) by taking average amounts of snow and average mercury concentration in the meltwater for each area and by adding the areas (Table 3). Over the total area, the snow concentrations can account for an input of about 50 tonnes of mercury per year.

Table 1. Mean mercury concentrations (ng·L^{-1}) in triplicate samples of meltwater from snow collected from sea ice offshore from arctic communities, together with minimum, maximum and blank values.

Community	Date Sampled	Mean Hg	Minimum	Maximum	Blank	Mean minus blank
Pelly Bay	21-Apr-98	85.2	42.7	107.4	1.3	83.9
Baker Lake	23-Apr-98	2.1	1.3	3.2	1.1	1.0
Tasiujaq	8-Apr-98	39.1	16.5	56.3	Leaked	39.1
Taloyoak	29-Apr-98	5.3	2.6	7.1	1.1	4.1
Cambridge Bay	27-Apr-98	237.1	158.0	360.7	0.9	236.2
Sanikiluaq	1998	17.2[*]	9.1	25.4	1.1	16.2
Whale Cove	26-Apr-98	28.5	12.7	45.7	0.3	28.2
Clyde River	13-May-98	64.8	60.2	68.0	0.6	64.2
Resolute	6-May-98	28.9	8.3	60.6	0.7	28.2
Kimmirut	1-May-98	3.2	2.9	3.5	0.6	2.6
Gjoa Haven	6-May-98	31.3	24.7	36.2	0.5	30.8
Arctic Bay	1998	73.0	22.1	100.2	0.6	72.4
Iqaluit	4-May-98	32.0	7.8	54.1	0.6	31.3
Grise Fiord	1-Jun-98	43.5	33.2	59.0	0.8	42.6
Beaufort (SHEBA site, after melt)[#]		1.4	1.3	1.5	0.5	0.9
Beaufort (SHEBA site, after melt)[#]		2.9	1.9	4.6	0.5	2.4
Beaufort (SHEBA site, after melt)[#]		4.5	2.6	7.7	0.5	4.0

[*] n=2, one bottle leaked

[#] excluded from mean calculation, samples taken after melt.

Table 2. Summary of mercury concentrations in meltwater from snow samples taken in 1997 and 1998.

	1997	1998
Mean (after subtraction of blank)	45.5	40.5
Minimum	0.9	0.9
Maximum	156	236
Number of snow samples	34	17

Table 3. Calculation of amounts of mercury entering the Arctic Ocean with snowmelt water, based on snow analyses for 1997.

	Area (m^2)	Hg (ng·L^{-1})	Depth (cm)	Density g·cm^{-3}	Hg in the snow-pack (tonnes)
High Arctic Ocean	7.08 x 10^{12}	21	30	0.4	17
Hudson Bay	1.16 x 10^{12}	55	30	0.4	8
Baffin Bay/Davis Strait/ Labrador Sea	2.75 x 10^{12}	38	50	0.4	21
Canadian Archipelago0.71 x 10^{12}	45	30	0.4	4	
Total					50

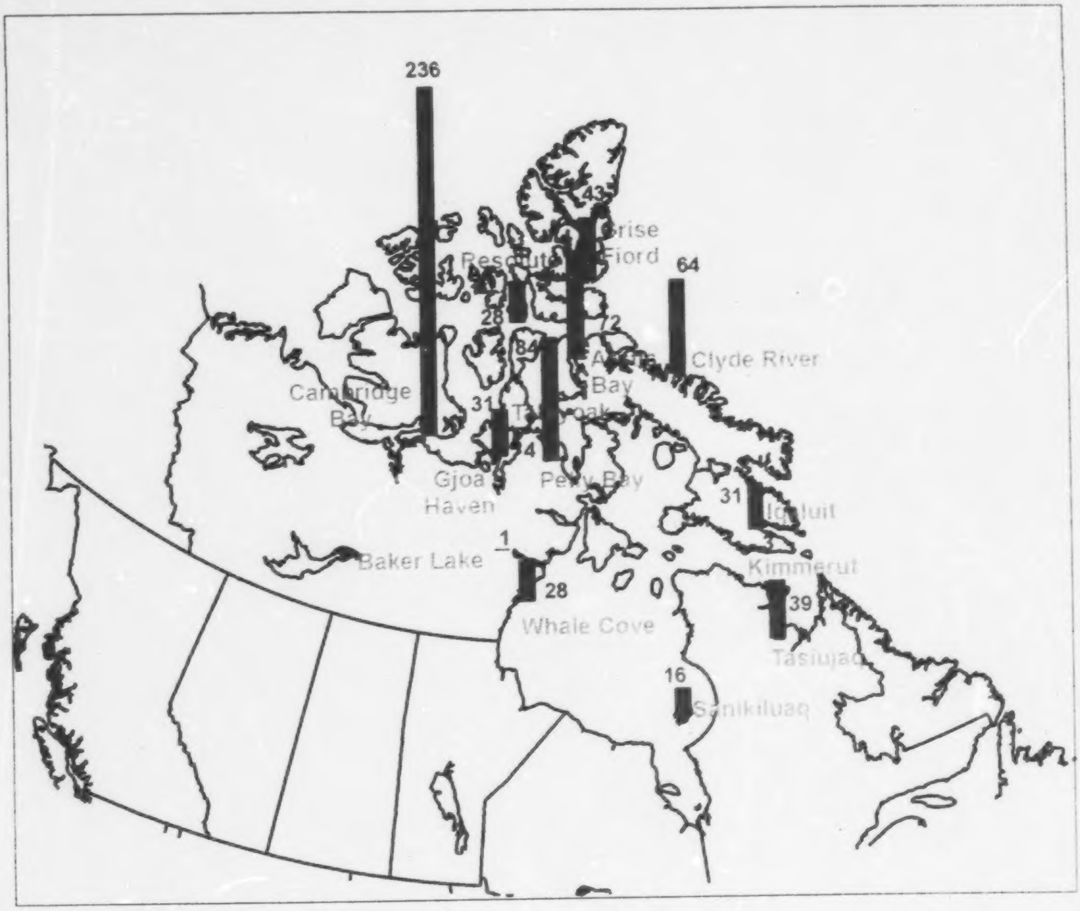

Figure 1. Histograms of snow meltwater concentrations (ng·L^{-1}) measured in snow collected from ice near Arctic communities from early April to June 1, 1998. The number near each bar is the concentration.

DISCUSSION/CONCLUSIONS

These studies are among the earliest direct measurements on inputs of mercury to the Arctic Ocean. Pacyna and Keeler (1995) used Eurasian and North American emissions data of about 1300 tonnes per year to calculate that about 60–80 tonnes per year should be deposited to the Arctic if mercury is dispersed similarly to sulfur. Our estimate of 50 tonnes per year (Lu *et al.* 1999) agrees well with the calculations by Pacyna and Keeler (1995). Another independent estimate of 23-46 tonnes per year was based on a flux of mercury to aquatic sediments of about 2-4 $\mu g \cdot m^{-2} \cdot y^{-1}$ (Lockhart *et al.* 1998). We should expect the lake sediment estimate to be somewhat low because not all the mercury entering a lake ends up in the sediment. Models of contaminant fate in arctic lakes have suggested that they retain relatively little of the total inputs of organic contaminants like DDT (Freitas *et al.* 1997) and the same may apply to mercury. The estimate by Pacyna and Keeler (1995) applies to a larger geographic area, namely the circumpolar Arctic and so reducing it to the areas used by the other two estimates would reduce the tonnage proportionately. However, in spite of the differences, the relatively close agreement among these three independent estimates begins to offer some constraints within which the deposition must fall.

Project Completion Date: March 31, 1999

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Ecosystem Contaminant Uptake and Effects

CONTAMINANTS IN ARCTIC SEABIRD EGGS

Project Leader: Birgit M. Braune, National Wildlife Research Centre (NWRC), Canadian Wildlife Service (CWS), Environment Canada, Hull, QC

Project Team: Brian Wakeford and Anthony Gaston, NWRC, CWS, Hull; Northern Contaminants Program (NCP), Department of Indian Affairs and Northern Development; Polar Continental Shelf Project, Resolute; Foods Directorate, Health Canada

OBJECTIVES

1. To collect eggs from five species of seabirds from Prince Leopold Island, Nunavut Territory, for analysis of chemical residues in order to monitor whether levels of contaminants in seabird eggs, as representative of the marine environment, are increasing or decreasing.

DESCRIPTION

The Canadian Wildlife Service (CWS) seabird egg monitoring program was established to monitor contamination of the marine ecosystem and possible implications for seabird health. As well, many Northerners harvest seabirds and their eggs for consumption (see harvest summaries in Wong 1985 and in Coad 1994). Monitoring of arctic seabird eggs for organochlorine residues has been ongoing on Prince Leopold Island in the Canadian High Arctic since 1975 and all unused portions of the egg samples have been archived in the CWS Tissue Bank. Metal levels can also accumulate to quite high levels in some seabird species, and the organic forms of mercury and selenium, which are the most toxic forms, are readily transferred to the eggs (Thompson 1996, Heinz 1996). Thick-billed murres, black-legged kittiwakes and northern fulmars have been monitored since 1975, and black guillemots and glaucous gulls, since 1993.

ACTIVITIES IN 1998/99

In 1998, eggs of five species of arctic seabirds (northern fulmar, thick-billed murre, black-legged kittiwake, black guillemot, glaucous gull) were collected from Prince Leopold Island (74°02'N, 90°05'W) in the Canadian High Arctic. Fifteen eggs per species per site were collected by hand on the basis of one egg per nest. Eggs were analyzed for total mercury, selenium and organochlorines including PCBs. The eggs were analyzed as pools (composite samples) of 3 eggs each. Collection, storage and analytical protocols specified by the National Wildlife Research Centre (NWRC), Hull, QC, were followed. The resulting data have been submitted to Health Canada for evaluation of risk to human consumers of the eggs.

RESULTS

The mercury and selenium data for eggs collected in 1998 have been statistically analyzed in the context of retrospective data for eggs of thick-billed murres, black-legged kittiwakes and northern fulmars monitored since 1975 (see Braune 1999). Levels of total mercury have shown a significant increase from 1975 to 1998 in thick-billed murres ($p<0.00001$) and northern fulmars ($p<0.0003$) (Figure 1). Mercury concentrations in black-legged kittiwakes have not changed significantly over time. Selenium levels showed a weak decline in northern fulmars but not in the other two species. Preliminary analysis of the 1998 organochlorine data (Table 1) suggests that concentrations are continuing to decline or are leveling off.

DISCUSSION/CONCLUSIONS

Since many contaminants biomagnify with increasing trophic level, differences in diet can significantly affect exposure to contaminants. As well, since these species are migratory, contaminant levels on the overwintering grounds must be considered in the interpretation of the contaminants data. Kittiwakes preferentially feed on small surface-schooling fish (Gaston and Nettleship 1981) but also glean crustaceans and plankton from the surface (Furness and Barrett 1985). Northern fulmars also feed on fish and amphipods taken at the surface or during shallow dives (Bradstreet 1976) as well as carrion (Hobson and Welch 1992). Murres from Prince Leopold Island are pursuit divers feeding on fish and crustaceans (Gaston and Bradstreet 1993, Gaston and Nettleship 1981). Although there are some interspecific dietary differences, these three species all feed at the same trophic level.

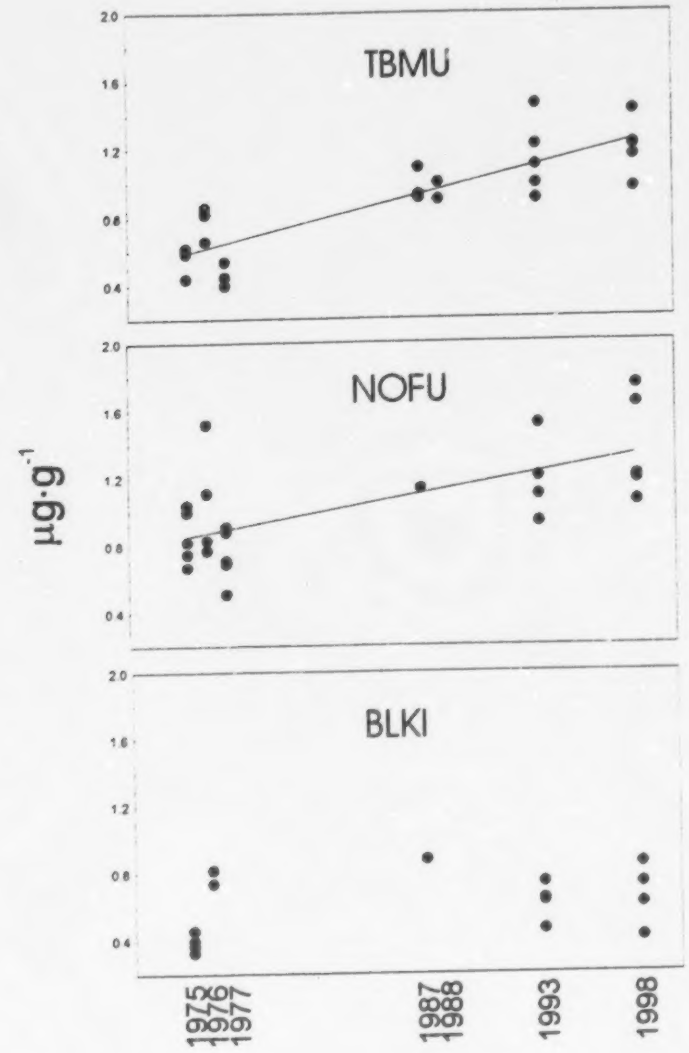

Figure 1. Mercury concentrations in eggs of Black-legged Kittiwake (BLKI), Northern Fulmar (NOFU), and Thick-billed Murre (TBMU) from Prince Leopold between 1975 and 1998.

Table 1. Mean organochlorine concentrations (mg/kg wet weight) in seabird eggs collected in 1998 from Prince Leopold Island

Species[1]		% Lipid	ΣPCB[2]	DDE	ΣCHL	DIELDRIN	ΣMIREX	ΣCBz	ΣHCH
BLGU	N[3]	5	5	5	5	5	5	5	5
	Mean	10.8	0.102	0.044	0.047	0.017	0.003	0.045	0.018
	Std.Error	0.4	0.003	0.002	0.005	0.003	0.0003	0.002	0.001
BLKI	N	5	5	5	5	5	5	5	5
	Mean	9.0	0.280	0.060	0.032	0.009	0.007	0.029	0.005
	Std.Error	0.2	0.022	0.008	0.002	0.0002	0.001	0.004	0.001
GLGU	N	5	5	5	5	5	5	5	5
	Mean	8.8	3.87	2.20	0.370	0.033	0.108	0.247	0.070
	Std.Error	0.2	0.509	0.216	0.038	0.005	0.015	0.023	0.005
NOFU	N	5	5	5	5	5	5	5	5
	Mean	11.3	0.267	0.192	0.096	0.014	0.013	0.035	0.0002
	Std.Error	0.4	0.020	0.020	0.010	0.001	0.001	0.004	0.0000
TBMU	N	5	5	5	5	5	5	5	5
	Mean	12.9	0.129	0.100	0.029	0.016	0.003	0.053	0.017
	Std.Error	0.4	0.009	0.008	0.004	0.002	0.0005	0.003	0.001

[1] BLGU - Black Guillemot; BLKI - Black-legged Kittiwake; GLGU - Glaucous Gull; NOFU - Northern Fulmar; TBMU - Thick-billed Murre

[2] ΣPCB - Sum of 67 congeners; ΣCHL - Sum Chlordanes (oxychlordane, *cis*- & *trans*-nonachlor, *cis*- & *trans*-chlordane, heptachlor epoxide); ΣMirex - Sum Photo-mirex & Mirex; ΣCBz - Sum Chlorobenzenes (tetra-, penta- & hexachlorobenzene); ΣHCH - Sum Hexachlorocyclohexanes (α-, β- & γ-HCH)

[3] N = number of composite/pooled samples of 3 eggs each

Since these birds breed on Prince Leopold Island but migrate elsewhere to overwinter, contaminants found in the eggs may originate at other latitudes. The exact winter distribution of kittiwakes from Prince Leopold Island is not known but kittiwakes are found along the eastern seaboard of North America from Newfoundland (Brown 1986) to Florida (Robertson and Woolfenden 1992) during the winter months. Northern fulmars breeding in the Canadian Arctic likely overwinter on the open seas of the Northeast Atlantic and into the North Sea (Hatch and Nettleship 1998). Band return data for thick-billed murres indicate that the murres from Prince Leopold Island overwinter in the open waters off southwestern Greenland (Donaldson *et al.* 1997).

The data presented in Figure 1 suggest that murres and fulmars have been exposed to increasingly greater concentrations of mercury over time than have kittiwakes. Given that these two species spend a greater proportion of the year at higher latitudes than do kittiwakes, the data suggest that risk of exposure to mercury is greater at higher latitudes. Seabirds from the northeast Atlantic and sub-Antarctic have also shown increases in mercury concentration over time (Thompson *et al.* 1993, Thompson *et al.* 1992). As well, similar increasing trends have been observed in beluga whales and ringed seals (Wagemann *et al.* 1996). Mercury levels have been reported to have increased over time in the sediments of northern lakes both in Canada and in Scandinavia (Lockhart *et al.* 1995, Mannio *et al.* 1995). The best explanation for this pattern is the ability of mercury to convert to a highly mobile gas which is easily transported to the Arctic where it is deposited and retained as a result of low air and water temperatures (AMAP 1998). Contrary to trends in arctic seabird eggs, eggs of seabirds in the more southerly Great Lakes showed declines in mercury concentration between 1972 and 1992 (Koster *et al.* 1996). Since the Great Lakes are temperate compared with the Arctic, the decreasing levels in these eggs may reflect a reduction in local anthropogenic mercury contamination of the environment combined with a gassing off into the atmosphere.

The interaction between mercury and selenium, where each counteracts the toxicity of the other, is well documented (Cuvin-Aralar and Furness 1991). Selenium concentrations in eggs did not show any association with mercury levels; in fact, the levels appear to be declining. At this time, we have no explanation for this pattern.

Compared with earlier published data for organochlorines in arctic seabird eggs (Nettleship and Peakall 1987, Noble and Elliott 1986, SOE 1990), most of the 1998 organochlorine data for the murres, kittiwakes and fulmars show a continuing decreasing trend or a plateauing of levels.

Levels of mercury, selenium and organochlorine compounds found in the 1998 seabird eggs were below known effect concentrations for eggs of wild birds. Due to the increasing trend of mercury levels, however, future monitoring is warranted.

Expected Project Completion Date: This is part on an ongoing monitoring program. The next sampling period will be in 2003. Funding was received for 1999/2000 for a retrospective analysis of organochlorines in archived seabird eggs. Results from the 1998 collections will be published as part of a manuscript on contaminant trends over time in the High Arctic by 2001. Pending future funding, a comparison of other available data sets on contaminant time trends with the seabird data will be undertaken in 2000/2001.

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ARSENIC LEVELS IN BERRIES AND SOILS FROM THE YELLOWKNIVES DENE FIRST NATION TRADITIONAL TERRITORY

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Project Team: Denise Maxwell, Dene Nation Lands and Environment Department; Glen Stephens, Contaminants Division, Department of Indian Affairs and Northern Development (DIAND); Elders, Yellowknives Dene First Nation

OBJECTIVE

1. To help determine if the traditional foods of the Weledeh Yellowknives Dene are safe to eat.

DESCRIPTION

More than two decades have passed since people in Yellowknife became aware of problems associated with arsenic (As), and vast improvements have since been made in the gold mining industry. There have been many studies conducted on arsenic levels in the environment around the Northwest Territories, some of which have dealt with traditional foods. Research results have been documented for As levels in soils (Government of Canada *et al.* 1993), air (GNWT 1996), fish (Jackson *et al.* 1996, Wagemann *et al.* 1978), sediments (Jackson *et al.* 1996, Wagemann *et al.* 1978) and water (Wagemann *et al.* 1978) around the Yellowknife area. There have also been tests for human health concerns associated with As poisoning (Canadian Public Health Association 1978). There is, however, little literature available on As levels in berries from Yellowknife, although berries were traditionally important to the Dene. Berries provide a rich supply of vitamin C, fibre and carbohydrates (Alaska Magazine editors 1982) and were traditionally eaten as 'sweets' (J. Charlo; H. Tobie; pers. comm. 1999). This study provides part of the full picture on the state of indigenous foods in the Weledeh Yellowknives Dene traditional area.

At low levels, arsenic is present in all living things and occurs everywhere in the environment. There has been some suggestion that As may be a micro nutrient, although this has not been documented (Phillips 1990). However, at higher than trace levels, environmental and health problems can occur.

There are two broad categories of As in the environment. The As contained in most foods is organic and gets excreted soon after ingestion. Food is the greatest source of As uptake in humans (NRC 1976), most of which is in the organic form. Although there is little data to determine how much organic As is safe for consumption, it is believed to leave the body quickly with very low toxicity (World Health Organization 1989). Therefore, As in foods such as caribou and fish can be at a fairly high level without being toxic to the consumer, although the tolerable level has not been agreed upon.

Arsenic is also present in the inorganic form. This is the most toxic form and is the form that is usually found in water. Arsenic, in the inorganic form, is on the Priority Substances List, established by the Ministers of Environment Canada and Health Canada. This list identifies all substances that can be harmful to the environment or cause human danger (Government of Canada *et al.* 1993). Since As is assessed to be toxic, regulations have been developed to control all aspects of the life cycle.

In Canada, As is released into the environment primarily from base-metal and gold production. Mining is one of the main employers of, and the largest single tax base in the NWT (Scott 1984) with 1500 people employed directly and 3000 indirectly, and another 500 in exploration (NWT Chamber of Mines 1999). Mining has caused a dramatic change in the Northwest Territories from the time prior to the 1930s. The mining industry once made Yellowknife one of the fastest-growing regions in Canada and has had a profound influence on the Yellowknives Dene First Nation, the Indigenous people who live there.

Gold mining is prominent throughout the Yellowknives Dene traditional territory. At gold mines with ore roasters, such as the Giant Yellowknife Mines, As can escape into the air and go through the environment under certain conditions (Government of Canada *et al.* 1993). Early mines had little or no environmental control on disposal of wastes and mine wastes were deliberately expelled into waterways (Bernard 1983, Cornett *et al.* 1992, Marron 1989, Mudroch and Clair 1986, Mok and Wai 1989). Giant Yellowknife Mines and Miramar Con Mines, both in the Yellowknife area, were no exception to this. Giant Mines is still believed to be the most significant source of As in the Yellowknife area (GNWT 1996).

Arsenic became a problem for the Yellowknives Dene First Nation in the 1950s and 60s, a short time after gold production began in two locations close to the city (Weledeh Yellowknives Dene 1997). In late 1949, large amounts of airborne arsenic from gold mines settled into the snow (Heeler 1995). The Yellowknives Dene did not know of the dangers, even though there were signs posted warning people not to eat the snow or to drink meltwater, for the signs were written in English and they could not understand them. Many animals died after drinking the water; people and dogs lost hair from wading or bathing in it, and four children died from drinking melted snow or eating the snow (Weledeh Yellowknives Dene 1997). An article in the *Yellowknifer* in 1975 reports of a woman who died of cancer in 1974 and the autopsy showed that she had an abnormally high level of arsenic in her body. These people, once healthy, were getting strange illnesses. They were also told that they could not drink water from Great Slave Lake. They had to buy water from town and had to wash all plants and berries before eating them.

Since then, the Yellowknives Dene, or Weledeh people, as they call themselves, have been wary about their traditional foods (Weledeh Yellowknives Dene 1997). Today, they will not harvest berries or other traditional plants from areas around Giant or Con Mines, which used to be preferred berry-picking sites. They, along with many other people in Yellowknife, fear that plants near these mines are unfit to eat. Many Weledeh people do not pick berries around the city of Yellowknife. They are more comfortable harvesting from areas away from Yellowknife, such as Wool Bay and Edzo.

ACTIVITIES IN 1998/99

Sampling sites for this study were selected on the basis of their significance to the Yellowknives Dene, either in the past or in the present. Significant sites could be either places where berries used to be harvested, places believed to be contaminated by mine waste, or places with historical significance.

Berry samples were collected from areas traditionally occupied by the Weledeh Yellowknives Dene. These areas include the Yellowknife River around Baker Creek, the Ingraham Trail, south of Yellowknife along the Yellowknife Bay to Wool Bay on the east and the mainland south of Mac Lake on the west, Enodah (Trout Rock) on the east arm, north to the MacKay Lake area and points around the city of Yellowknife.

The berries collected for this study were traditionally important to the Yellowknives Dene and elders and youths still harvest these species. These species include raspberry (*Rubus idaeus*), cloudberry (*Rubus chamaemorus*), blueberry (*Vaccinium ovalifolium*), cranberry (*Vaccinium vitis-idaea*), rose hip (*Rosa acicularus*) and gooseberry (*Ribes lacustre*).

The study required samples to be taken from sites around active gold mines (Giant and Con), abandoned gold mines (Salmita and Burwash) and points around places where there has been no mining to be used as control. Elders and other knowledgeable Dene were consulted as to where the most appropriate places were to take the samples, based on traditional use of the area, and their knowledge as to where the most likely places were to find these berries. The control points were chosen because they, along with being traditionally significant to the Weledeh people, are several kilometres away from the mine sites. The Weledeh elders believe berries from these places are safe to eat. These points were the islands around Wool Bay, the west side of Yellowknife Bay, Enodah and Point Lake. Point Lake is not included on the Yellowknives Dene traditional map, as this area has no traditional significance to the Weledeh people. However, samples were taken from this area because it is far enough away from any active gold or base metal mine that it can be a very good control. The area is also in a greenstone belt like the Yellowknife and area samples. This study was conducted following the *Yellowknives Dene First Nation Policy Guidelines for Yellowknives Dene Traditional Knowledge (YDTK)*.

A visit was made to the Giant and Con mine sites early in the berry season to determine what species of berries were present. Flagging tape was used to mark the places where berries were found. Trips were also made around town to determine the presence of berry species.

Sample collecting began on July 13, 1998. Blueberries were harvested by the project coordinator from the Miramar Con Mine site. On July 17, raspberries were collected near the day-use area at Fred Henne Park. Sampling continued until September 28, when cranberries and rose hips were still in season. Throughout the study, berry samples were collected by Dene elders, the study coordinator, and the Lands and Environment Manager and Assistant Manager. Arsenic is taken up by plants primarily by the soil (Government of Canada *et al.* 1993) and variations in the soil can enhance or reduce arsenic uptake by plants (Xu *et al.* 1991). Therefore, to find potential arsenic uptake by the berries, a representative sample of soil was collected at root level. Due to the travel cost of going to the MacKay Lake area to take samples, expediters from Bathurst Arctic Expediting volunteered to collect samples while at their camp at Salmita. Similarly, outfitters from Enodah Wilderness Travel and Peterson's Point Lake Lodge gathered samples from areas around their camps at Trout Rock and Point Lake. Samples were collected

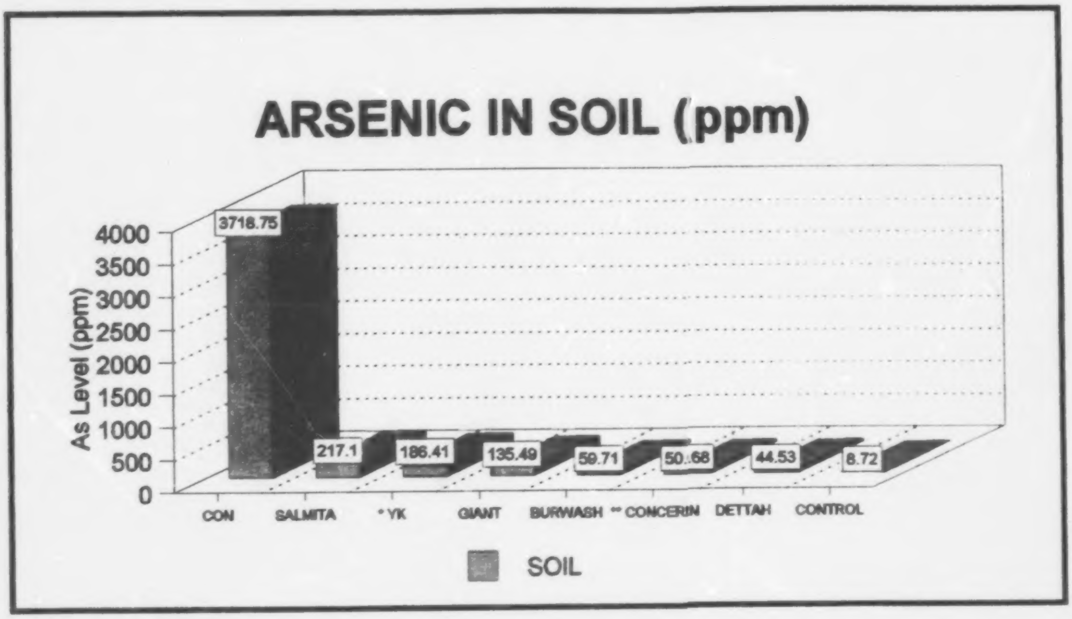

Figure 1. Mean arsenic levels (ppm) in soils from each location. * YK represents samples taken from the city of Yellowknife; ** CONCERN represents samples taken from areas the Weledeh elders believe to be contaminated (i.e. Yellowknife Bay west side, Kam Lake and Baker Creek).

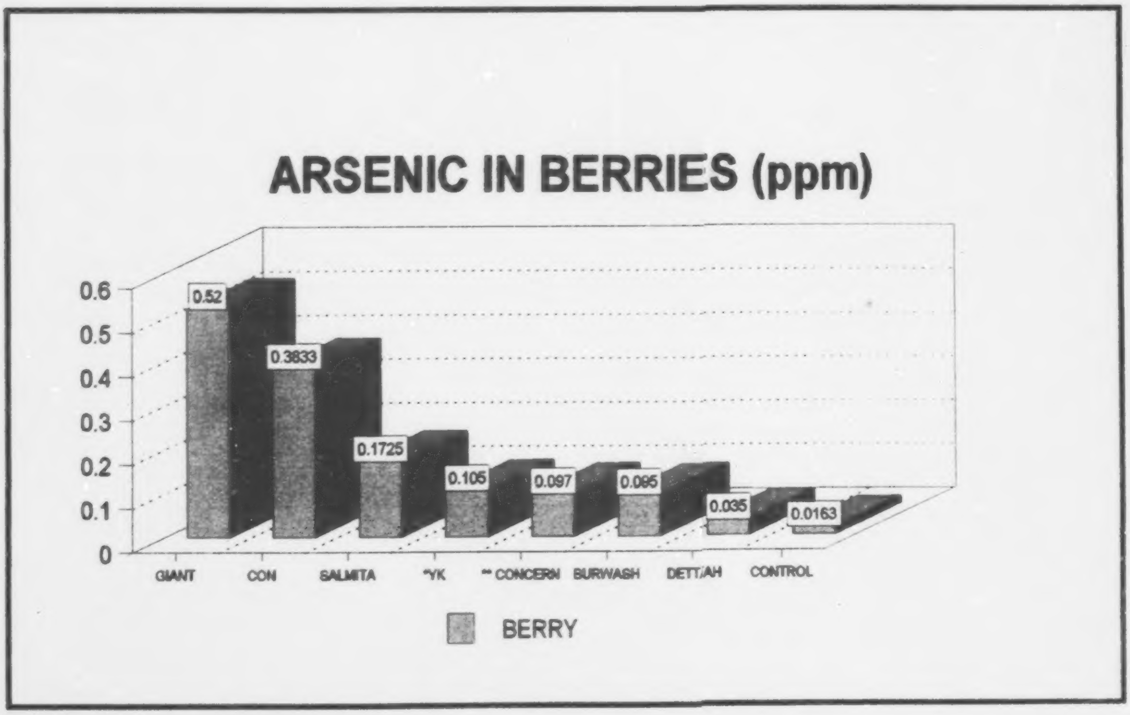

Figure 2. Mean arsenic levels (ppm) in all species of berries from each sampling location. * YK represents samples taken from the city of Yellowknife; ** CONCERN represents samples taken from areas the Weledeh elders believe to be contaminated (i.e. Yellowknife Bay west side, Kam Lake and Baker Creek).

Table 1. Berry samples from various locations throughout the study area found to exceed accepted guideline of 0.1 µg·g^{-1} As wet wt.

Location	*Berry*	*As level (µg·g^{-1} wet wt)*
Fred Henne Park, Yellowknife	Raspberry	0.2
Joliffe Island, Yellowknife	Blueberry	0.16
Joliffe Island, Yellowknife	Raspberry	0.13
Taylor Road, Yellowknife	Cranberry	0.15
Giant Mine (active)	Gooseberry	0.2
Giant Mine (active)	Raspberry	1.91
Giant Mine (active)	2 Cranberry	0.30, 0.46
Giant Mine (active)	Rose Hip	0.2
Con Mine (active)	2 Cranberry	0.32, 0.64
Con Mine (active)	2 Rose Hip	0.86, 0.23
Con Mine (active)	Gooseberry	0.18
Yellowknife River	Cranberry	0.19
Yellowknife River	Rose Hip	0.11
Baker Creek	Rose Hip	0.15
Salmita (non active)	2 Cloudberry	0.16, 0.32
Salmita (non active)	Blueberry	0.16
Across Bay from Giant Mine	Cranberry	0.12

following the procedure set by the laboratory staff at the Centre for Indigenous People's Nutrition and Environment (CINE) at McGill University in Montreal. All samples were frozen and shipped to the CINE Research Lab to be analysed for total arsenic. The results were analysed statistically using the Kolmogorov–Smirnov and Kruskal–Wallis methods by the project team and presented to the Yellowknives Dene First Nation.

A general description of the area was recorded at each sampling site. This included a description of neighbouring plant species, land topography, water availability and proximity to mine. Prevailing wind direction and general weather patterns during the berry season were also noted. These factors are important in studying arsenic because this element can travel long distances by wind, precipitation and dust, and uptake of As by biota is a complex interaction between these factors.

After the sampling was completed and samples were sent to the lab for analysis, interviews were conducted by the coordinator. Elders were interviewed to acquire information about traditional uses of berries, other plants used by the Yellowknives Dene, other traditional foods, the effect of the mining industry on them and their families, since many of them were children and young adults when the mining industry began in Yellowknife. They were also asked about the effect of As on the Yellowknives Dene, especially before pollution regulation and prior to the time when Dene people understood arsenic. A copy of the transcripts may be obtained with permission by contacting the Yellowknives Dene First Nation.

RESULTS

This study revealed a statistically significant difference between As in berries from both the control and Dettah sites compared with all other locations. The berry and soil samples from the mine sites and within the city of Yellowknife had statistically higher levels of As than those from the control sites (Figures 1 and 2). Unfortunately, there is no guideline level for As in berries. For this study, acceptable levels were determined by using the guideline of 0.1 ppm (0.1 µg·g^{-1}), used for fruit juices and beverages. Using this guideline, which was recommended by Dr. Laurie Chan of CINE, 21 of the 51 samples exceeded this guideline and were called unsuitable for human consumption (Table 1).

DISCUSSION/CONCLUSIONS

This study showed statistically higher levels of As in five species of berries (blueberries, cranberries, raspberries, rose hips, gooseberries) from areas around gold mines (and close to these mines) than from the control sites. The results suggest that gold mining has an effect on As levels in these species of berries in the Yellowknives Dene traditional territory. Most berries harvested at the mine sites and some harvested within the city of Yellowknife are above the recommended concentration of 0.1 µg·g^{-1} for consumption. Proximity to the active mine sites appears to be a significant factor determining the level of As in berries in this region, as berries from the Dettah sites, further away from the mine sites than the town samples, were statistically lower in As than those from the city of Yellowknife. Cloudberries were analysed in this study but there were insufficient samples to determine whether or not mining has an effect on this species.

Recommendations

1) Because there were many berry samples over the recommended 0.1 $mg \cdot g^{-1}$ As level ,the project team suggests that a further study be conducted to determine the species of As found in the berry species in the Yellowknives Dene First Nation traditional territory.
2) Until the species of As is determined, it is recommended to avoid harvesting berries on or near the mine sites (along with those from Baker Creek and Yellowknife River).
3) Berries from around the town site of Yellowknife had a mean As level of slightly above 0.1 $\mu g \cdot g^{-1}$. It is recommended that berries from Yellowknife be washed before consumption. This same recommendation is made for berries harvested from the Yellowknife Bay east side, across from Giant Mine.
4) Berries from all other locations may be harvested and consumed without discretion, as the As levels in the berries and soils are very low.

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Tobie, H. 1999. Knowledgeable Weledeh Yellowknives Dene Elder

BUTYLTIN CONTAMINATION IN BELUGA WHALES (*Delphinapterus leucas*) FROM THE ST. LAWRENCE ESTUARY AND NORTHERN QUEBEC.

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OBJECTIVES

1. To evaluate the contamination of beluga whales from northern Quebec by the antifouling agent tributyltin (TBT) by establishing the levels of contamination for liver, skin and meat, and to discuss the risk for human contamination by TBT through consumption of beluga whales.
2. To compare the TBT levels in beluga whales from northern Quebec with those in beluga whales from the St. Lawrence Estuary (this part of the project was funded by a FODAR (Fonds de Développement Académique du Réseau) grant to S. de Mora).

DESCRIPTION

Widespread usage of tributyltin (TBT) as an antifouling agent in boat paint has led to marked contamination of freshwater and marine coastal ecosystems (de Mora 1996). TBT is very toxic for aquatic organisms and has been described as the most poisonous compound ever introduced by humans into the aquatic environment (Goldberg 1986). Canada has regulated the use of organotin-based paints since 1989; specifically, their application was prohibited on boats <25 m. However, recent studies have revealed persistent TBT contamination of marine waters in Canada (Chau *et al.* 1997) and in sediments and mussels from the St. Lawrence Estuary (St.Louis *et al.* 1997).

The potential bioaccumulation of TBT by higher aquatic trophic organisms had been considered to be low until a research group from Japan reported the contamination by organotin compounds of cetaceans and pinnipeds in various regions of the world. The highest concentrations, as measured in the liver of the animals, were observed in coastal species (Tanabe *et al.* 1998). Similar results were found in ten-year-old liver samples from beluga whales found stranded along the coasts of the St. Lawrence Estuary before the use of TBT-based paints was regulated in Canada (Yang *et al.* 1998).

There is an emerging concern about TBT contamination in remote marine coastal environments. The beluga whales living in Canadian Arctic waters are obviously less exposed to TBT originating from shipping activities than those in busy shipping zones further south, however, studies by Tanabe *et al.* (1998) have revealed TBT contamination of Dall's porpoises collected as far remote as the Aleutian Chain in the north Pacific Ocean. As marine mammals are an important food resource for the human inhabitants in northern regions, the question arises about the risk of biotransfer to human consumers, particularly given that the presence of butyltin compounds in human tissues has recently been observed (Kannan and Falandysz 1997).

This investigation of beluga whales from two study sites with contrasting levels of shipping activity provides the levels of hepatic contamination of butyltin compounds, which are generally derived from the antifouling biocide tributyltin (TBT). The data from the beluga whales of the south (St. Lawrence Estuary) cover the period 1995-98 and, together with data from Yang *et al.* (1998), provide an estimation of the temporal trend of butyltins contamination in whales living in the vicinity of a major shipping route. In contrast, the data from the beluga whales from the north (Hudson Strait) provide a baseline level of contamination for marine mammals inhabiting a pristine coastal environment.

ACTIVITIES IN 1998/99

In the summer of 1998, seven adult beluga whales were collected from the Hudson Strait (Figure 1). Liver, skin (muktuk) and meat samples were collected from each beluga whale (~ 100 g per organ). Sample collection was conducted by the local Hunting, Fishing and Trapping Association of Kangiqsujuaq. Gender and colour were recorded and a tooth from each animal was collected for estimating the age of the animal. Samples

Table 1. Concentrations of butyltin compounds in beluga liver samples (MBT, monobutyltin; DBT, dibutyltin; TBT, tributyltin). Concentrations are expressed as ng Sn·g^{-1} dry wt.

Sample[a]	Sex	Age (year)	Length (cm)	MBT	DBT	TBT	ΣBTs	TBT/DBT
Hudson Strait								
98348	M	17	N/A[c]	n.d.[d]	n.d.	n.d.		
98349	F	11	N/A	n.d.	n.d.	n.d.		
98358	M	N/A	N/A	n.d.	n.d.	n.d.		
98359	F	>15[e]	N/A	n.d.	n.d.	n.d.		
98482	F	N/A	N/A	n.d.	n.d.	n.d.		
St. Lawrence Estuary								
9507	M	0	199	1	132	111	244	0.8
9508	F	0	157	7	57	67	130	1.2
9509	M	1.5	247	26	735	116	877	0.2
9511	M	26+[e]	419	399	282	84	764	0.3
9512	M	11	400	6	53	8	66	0.2
9601	F	21+	427	9	250	22	281	0.1
9602	F	5	325	9	45	n.d.	54	
9604	M	16++[e]	420	n.d.	96	n.d.	96	
9607	M	24+	399	11	100	n.d.	111	
9609	M	23++	393	23	188	n.d.	210	
9608	F	1.2	216	17	137	n.d.	153	
9701	M	8	396	7	229	101	336	0.4
9702	F	28.5	338	7	141	58	205	0.4
9703	F	21+	363	6	1613	467	2085	0.3
9704[b]	M	0	139	9	12	15	36	1.2
9705	M	7.5	378	14	160	40	214	0.3
9706	F	31+	385	10	716	308	1034	0.4
9802	M	N/A	401	9	294	14	316	0.1
9803	F	N/A	377	27	289	27	342	0.1
9804	F	N/A	356	16	208	n.d.	224	
9806	F	N/A	388	16	54	28	98	0.5

[a] The first two digits indicate the year the whale was found stranded.

[b] This beluga whale was a neonate.

[c] N/A, not available

[d] n.d., not detected

[e] The aging of whales is not an exact science; the age shown is a lower estimate and the age could actually be somewhat greater, in order of >, +, and ++. The >, +, and ++ signs are also related to the state of the tooth used to establish the age of the whale. for example, ++ means that the tooth was damaged (i.e. layers were not very distinct) and extrapolation was done to estimate the age.

were frozen and sent to the Nunavik Research Centre for storage until they were shipped to the Department of Ocean-ography at the Université du Québec à Rimouski for chemical analysis. Liver samples from 21 beluga whales found stranded along the shores of the St. Lawrence Estuary between 1995 and 1998 were provided by University of Montreal's Faculté de Médecine Vétérinaire.

RESULTS AND DISCUSSION

Butyltin compounds in beluga whales from northern Quebec

We analysed five liver samples out of the seven beluga whales originating from northern Quebec. No butyltin compounds were detected in the liver samples (Table 1). Because the liver is the target organ for butyltins contamination in marine mammals (Tanabe *et al.* 1998) and no butyltins were detected in the liver, we did not analyse the meat and skin samples. This finding contrasts with data published on the butyltin contamination of whales from remote areas (Tanabe *et al.* 1998) and the notion of global TBT pollution in the marine environment as proposed by Yamada *et al.* (1997), based on observations of contaminated squid liver. In comparison to the heavy commercial traffic in the St. Lawrence Estuary, the shipping activities in northern Quebec are very limited. In 1991, eight cargo ships and five tankers made round trips and were supported by icebreakers of the Canadian Coast Guard when necessary (Canadian Coast Guard 1991). This maritime traffic is most likely insufficient to provide an appreciable input of TBT into the marine environment of northern Quebec.

Yamada *et al.* (1997) have suggested, but not evaluated, the atmospheric transport of organotin to the remote marine environment. It is well documented that marine mammals inhabiting the Arctic are contaminated by various organochlorine compounds due to the long-

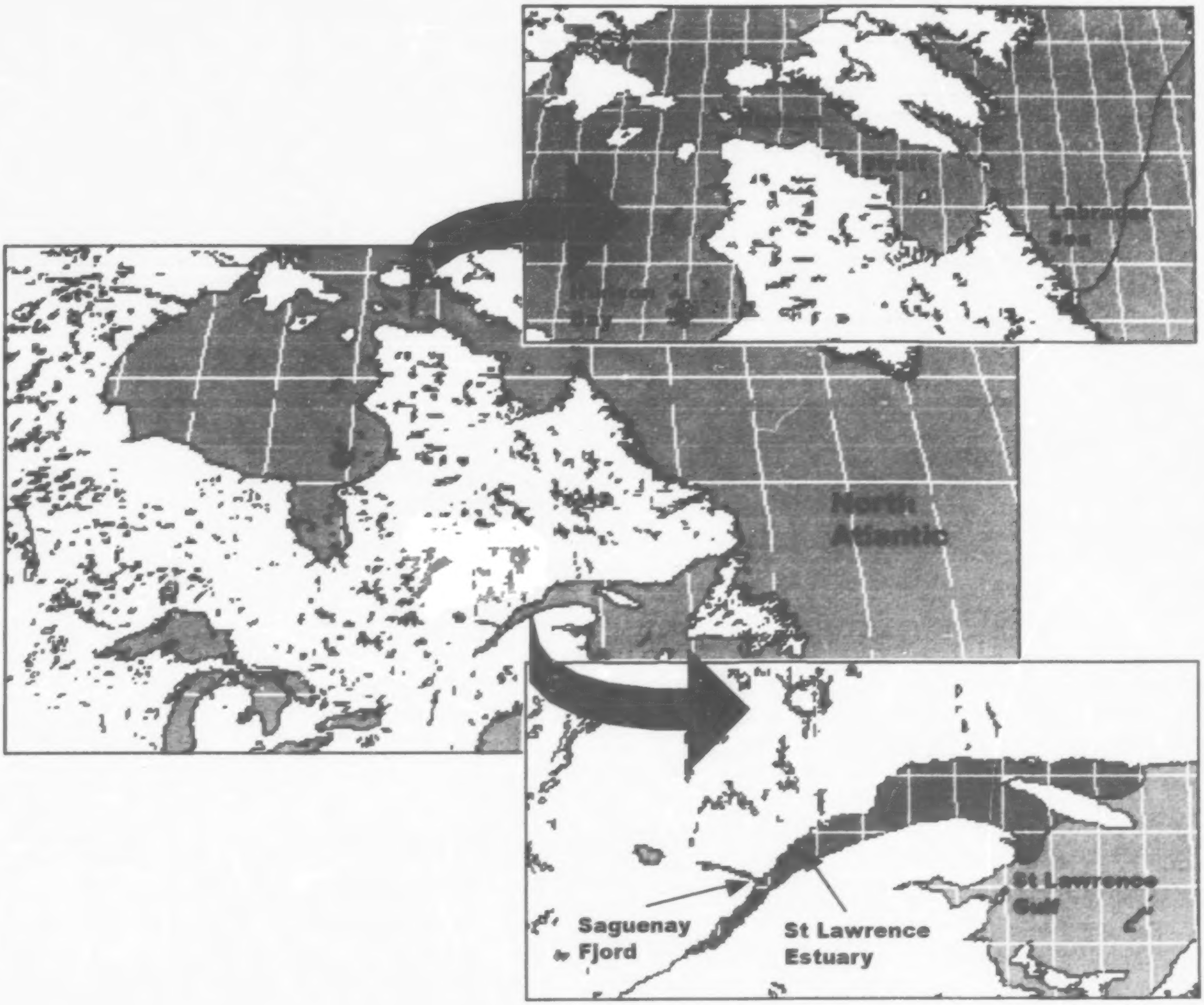

Figure 1.

range aerial transport of these pollutants (Muir *et al.* 1990, Metcalfe *et al.* 1999). In fact, the analysis of the liver samples of these beluga whales from the Hudson Strait showed their contamination by organochlorine compounds. The mean concentrations were (n=5, concentrations are expressed in pg·g^{-1}): ΣDDT 13 202 ± 9559; ΣPCB 19 540 ± 15 410; and Σchlordane 242 ± 133 (Brochu, *unpublished data*). Thus, the beluga whales from the Hudson Strait are probably exposed to the atmospheric input of organochlorine compounds. However, since no butyltin compounds were detected in their livers, it is unlikely that aerial input could be a source of organotin compounds to the Arctic whale populations.

As the analyses failed to detect the presence of butyltin compounds in the beluga liver from Hudson Strait, the risk of human exposure to theses compounds by the consumption of beluga meat of animals hunted in the Hudson Strait area is nil.

Butyltin compounds in beluga whales, St. Lawrence Estuary 1995-1998.

In contrast to organochlorine compounds, butyltin compounds are not persistent pollutants in an organism and concentrations should reflect recent accumulation. If metabolism and elimination processes are not affected by the toxic stress due to TBT, butyltin concentrations should decline if the uptake ceases (Fent 1996).

Butyltin compounds were present in all liver samples from beluga whales of the St. Lawrence Estuary (Table 1). Total butyltin concentrations varied from 36-2085 ng Sn·g^{-1} (dry wt). These concentrations are similar to those reported for cetaceans from the North Pacific, Asian coastal waters and the Atlantic coast of the USA (Tanabe *et al.* 1998, Kannan *et al.* 1997). There was no clear relationship between the butyltin concentrations in the liver and the body length of the specimen, however, the highest concentrations were found in larger (older) animals. There was also no significant difference in butyltin concentrations between male and female whales; T-test calculations based on the ratio ΣBTs:body length gave t=0.63 with the critical value of t (P=0.05) being 2.14. This finding agrees with reports for other cetaceans (Tanabe *et al.* 1998, Kim *et al.* 1996). Finally, year-to-year differences are not obvious even when the data for beluga found stranded in 1988 (Yang *et al.* 1998) are included. ANOVA calculations based on the ratio ΣBTs:body length gave F=1.44 with the critical value of F (P=0.05) being 2.84. This indicates there has been no significant variation in the contamination of this whale population since the introduction of Canadian regulations in 1989 prohibiting the use of organotin-based paints on vessels less than 25 m in length. Moreover, the highest concentration was detected in a female stranded in 1997 (2085 ng Sn·g^{-1} in liver sample No. 9703; Table 1).

Nevertheless, these observations clearly indicate that TBT input into the marine environment of the St. Lawrence Estuary is still a matter of concern after ten years of restrictions. Recreational boating activities are marginal in the estuary, particularly considering that it is ice-covered during the winter months. Although other sources of organotin compounds, such as the effluents from sludge treatment plants of large cities along the St. Lawrence River (Chau *et al.* 1997) are possible, the predominant source of TBT is most likely to be commercial shipping. In 1992, about 7000 large commercial vessels (94.5 x 10^6 T) navigated the estuary (Centre St-Laurent 1996). The butyltin concentrations of the beluga whales inhabiting these waters confirm the susceptibility to TBT-contamination for marine organisms living in close proximity to a major shipping route (de Mora 1996, Davies *et al.* 1998).

CONCLUSIONS

A sample of the beluga whale population of the Hudson Strait, northern Quebec, had no detectable levels of organotin compounds in its liver tissues. In contrast, all individuals from the St. Lawrence Estuary were contaminated with butyltin compounds, thereby confirming the susceptibility of TBT exposure for marine organisms living in the vicinity of a major shipping channel.

Expected Project Completion Date: For funding received in 1998/99 the project is complete and a scientific paper has been submitted to the international journal entitled *Applied Organometallic Chemistry*.

Acknowledgments

We thank the local Hunting, Fishing and Trapping Association of Kangiqsujuaq for collection of biodata and tissue samples from beluga whales. We also thank Charles Brochu of the Centre d'Expertise en Analyse Environnementale du Québec, Ministère de l'Environnement et de la Faune du Québec, for providing results of the analyses of organochlorine compounds in samples from northern Quebec. This work has received financial support from FIR-Université du Québec à Rimouski, FODAR, and the Department of Indian Affairs and Northern Development, Canada (DIAND).

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COMMUNITY-BASED MONITORING OF ABNORMALITIES IN WILDLIFE

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OBJECTIVES

1. To develop a community-based monitoring program in which harvesters can document and communicate observations of changes in wildlife in a systematic and useful way.
2. To provide an "early warning system" to detect changes or patterns in wildlife health at an ecosystem level. This systematic monitoring may identify areas requiring further study and aid in hypothesis development.
3. To integrate scientific and traditional ecological knowledge to increase general understanding of changes in the health status of wildlife.
4. To allow communities to participate and build local capacity to identify, investigate and respond to changes in the wildlife resources they harvest.

DESCRIPTION

Communities across the Northwest Territories have a long history of dependence on wildlife and the environment. The traditional subsistence harvesting of fish, terrestrial wildlife, marine mammals and migratory birds provides Northerners with significant nutritional, economic, social and cultural benefits. Traditional pursuits such as hunting, fishing and trapping have long been the basis of the northern economy. The replacement value of traditional/country food and other renewable resources is approximately $60 million per year (1990 dollars; Lloyd and Graf 1991). Confidence in the health of wildlife populations and the availability of safe and healthy meat is extremely important for the maintenance of both subsistence harvesting and the commercial use of wildlife.

Changes in wildlife health can have significant impacts on individual animals and population health, as well as human use of the resource. Although most wild animals are healthy, abnormalities such as diseases, parasites, tumours and deformities can occur in any wildlife population. Some conditions appear to be increasing in frequency or appearing in new areas of the North. Local people want to know if there is a connection between the environmental contaminants they are being told about and their observations of unusual changes or abnormalities in wildlife. Documenting the occurrence of these changes is the first step in addressing these questions. These questions may serve as a sentinel for identifying problems that require further investigation. Such documentation may also focus attention on linkages between observed changes and known effects of specific contaminants, and assist in developing testable hypotheses.

Information on abnormalities in wildlife is currently obtained in several ways. There have been a number of specific studies focussing on particular aspects of wildlife health in individual species. Changes are also noted opportunistically when handling animals during other wildlife studies or commercial wildlife harvests. Samples or reports of abnormalities are occasionally brought in to Renewable Resource Officers by hunters who come across unusual findings, but this system is primarily a reactive process to individual cases. Under this system, the number of samples or observations received is low compared to the number of animals harvested, the expertise and experience of harvesters in recognizing abnormalities or other changes in the health of wildlife are not fully accessed, and it is difficult to differentiate localized versus widespread patterns.

Through their land-based subsistence lifestyles, local hunters have developed a wealth of experience and understanding of the ecosystems in which they live. Experienced hunters spend large amounts of time observing wildlife, and can recognize changes in animals and trends in the occurrence of some conditions over time. This field of ecological knowledge is commonly known as Traditional Ecological Knowledge (TEK), and includes empirical knowledge gained through experience and observation. This is consistent with western science, where experience and observation form the basis of modern empirical research. The scientific process differs in that it has developed a formal method by which these experiences and observations can be systematically documented and verified. The opportunity exists to integrate these two systems to increase information on changes in wildlife health, and to increase trust and cooperation between resource harvesters and researchers.

ACTIVITIES IN 1998/99

In the first two years of the project, an emphasis was placed on capacity-building in the communities through local training sessions, and the development of resource materials to support this work.

i) Local Training Sessions

To date, a wide range of training and information sessions have been held in each of the three participating communities (Kugluktuk, Fort Good Hope, Fort Resolution). As the emphasis is on community participation, these sessions have targeted a wide range of community groups including local resource harvesters (hunters and trappers), food preparers, elders, students, local environmental committees, and interested members of the general public. These sessions were designed to introduce the project, provide background information on wildlife health, and begin to build local capacity to manage the project and respond to changes in the wildlife resources they harvest. The goal of the training component of this work is to build capacity within the community to deal with abnormalities in a timely fashion on a local basis. While the intensive period for training has been completed, some additional sessions will be provided as required.

In addition to community-based workshops and meetings, field training courses were held in Fort Resolution (September 18-21, 1998 and February 23-27, 1998) and Kugluktuk (March 19-22, 1998 and November 5-8, 1997). Local hunters, elders and students participated in hands-on training in the field, applying information and techniques from the training sessions on harvested animals in the field.

ii) Development of Resource Material

A self-contained package of resource materials has been developed to assist with implementation of the project. This package is used by the community coordinators and resource harvesters to assist with uniform collection and recording of information, sample collection and testing, and interpretation and reporting of results. The resource kit includes project manual, a hunter/elder survey form, standardized disease observation and sample submission forms, visual (photographic) reference guides to assist with identification of abnormalities, and field sampling kits. Resource materials are predominantly in English, since there are multiple aboriginal languages involved in the three pilot project communities, although some components (eg. field data sheets) are also in Inuktitut. These materials were field tested during the first two years of the program, and are currently being updated and revised. A *Field Guide to Common Diseases and Parasites of Wildlife in the NWT and Nunavut* was also produced in 1998/99, and has been particularly well received in the communities as a tool for hunters to identify abnormalities and to make timely decisions on the implications for use of the carcass.

iii) Community-based Monitoring of Abnormalities in Wildlife

Community-based monitoring of abnormalities in wildlife began in 1997/98 and continued in 1998/99. Various approaches were considered to maximize the effectiveness of sample collection and documentation of observations from wildlife harvesters within each community. Information was collected on the occurrence of abnormalities in wildlife from all local hunters using written reports and/or samples for analysis, along with an additional formalized surveillance program focussing on several key harvesters in the community. Two field collections of caribou were also conducted to provide baseline data on their health status. This information will provide a benchmark for future comparison to evaluate changes in health status, and to provide a tool to help validate data collected by the community-based monitoring system using hunter submitted samples. Traditional Ecological Knowledge surveys on the occurrence of abnormalities in wildlife were also conducted with elders and experienced wildlife harvesters in each community.

iv) Traditional Ecological Knowledge Survey

Interviews were conducted with experienced, long-time local harvesters about the occurrence of abnormalities and disease in wildlife. The community coordinators, or alternate local wildlife harvesters, conducted the interviews. This eliminated the need for simultaneous translation, ensured the interviewer was familiar with the topic, and enabled elders to relax and share their knowledge of the subject. Results from the 1997/98 surveys are currently being evaluated.

Table 1. Diseases and parasites detected in Bluenose Caribou harvested near Kugluktuk.

CONDITION	FALL PREVALENCE (n = 26)	SPRING PREVALENCE (n = 26)	OVERALL PREVALENCE (n = 52)
Body Condition (mean back fat depth)	11.8 mm (range: 0-57 mm)	5.4 mm (range: 0-18 mm)	—
Brucellosis (*Brucella suis* biovar 4)	7.7 %	4.0 %	5.8 %
Warbles *(Oedemagena tarandi)*	44.4 % (range 3-145/animal)	100 % (range 8-182/animal)	73 %
Sarcocystis spp.	92.3 % (67 % mild, 29 % moderate, 4% severe)	100 % (92 % mild, 8 % moderate, 0% severe	96.1 %
Besnoitia spp.	46 % (1 clinical case; 11 +ve but not visible)	being completed	46 % *
Liver Tapeworms (*Taenia hydatigena*)	11.5 %	0 %	5.7 %
Muscle Tapeworms (*Taenia krabbei*)	0 %	0%	0%
Gastrointestinal Parasites (*Nematodirus*, *Moniezia* and *Eimeria* spp.	15.4 %	26.9 %	21.2 %
Protostrongylid sp. larvae	19.2 % (range 42-544/gram)	38.5 % (range 1-125/gram)	28.8 %
Lungworm (*Dictyocaulus* sp.)	7.7 %	being completed	7.7 % * (2 cases)
Non-specific Infections	3.8 %	3.8 %	3.8 %
Developmental Anomalies	3.8 %	0 %	1.9 %
Tumours/Neoplasia	0 %	0 %	0 %

* based on Fall prevalence only

RESULTS AND DISCUSSION

This initiative is being conducted as a pilot project to test the concept, design and implementation of a community-based monitoring system in three Northern communities. The communities were selected to reflect regional differences in wildlife species and harvesting patterns: Kugluktuk (Arctic Coast), Ft. Good Hope (Mackenzie Valley) and Ft. Resolution (Slave River Delta). The project includes the delivery of local wildlife health/sampling workshops, routine communications with local hunters to document abnormalities in harvested wildlife, collection of samples from hunters for testing, organized field collections to provide baseline data to validate results from community-based sampling, and traditional knowledge surveys of respected hunters.

As a community-based process, a local coordinator has been identified in each community. This individual helps organize community wildlife health/sampling workshops, routinely talks with local hunters to document abnormalities in harvested wildlife (noting frequency of "abnormalities" compared to "normal" animals harvested), collects samples of abnormalities from hunters and submits them for testing, facilitates results reporting, and organizes traditional knowledge surveys of respected local hunters about abnormalities in wildlife. The system is designed to rely on key observers or monitors in each community who are recognized for their wildlife harvesting and observation skills.

The community-based monitoring program has been ongoing for the last two years to document abnormalities in wildlife. Documentation of observations by wildlife harvesters has been done through both sample and report collection from local hunters, and through a more formalized sample collection system using selected key harvesters in the community. This has provided information on both the types and proximate cause of abnormalities being seen by harvesters, and an estimate of frequency of their occurrence. A wide range of abnormalities has been reported by hunters and trappers, with the vast majority being "naturally occurring" diseases and parasites that occur in northern wildlife species. The frequently occurring conditions include brucellosis, tuberculosis, warbles, liver parasites (*Taenia hydatigena*), muscle parasites (*Sarcocystis* spp. and *Taenia krabbei*), gastrointestinal parasites (*Nematodirus* sp., *Moniezia* sp., *Eimeria* sp.), lungworms (*Dictyocaulus* sp.), Hydatid disease (*Echinococcus granulosus*), ticks (*Dermacentor albipictus*), physical injuries, and malnutrition. Very few tumours or developmental anomalies have been detected.

As a method to validate data collected under the community-based monitoring system using hunter submitted samples, a systematic disease survey was conducted during the same time period to compare the data on type and prevalence of abnormalities provided by both systems. Two field collections of caribou were conducted to provide baseline data on the health status and disease/parasite prevalence in caribou from the area being utilized by Kugluktuk hunters. Collections were held in both Fall and Spring in order to look at seasonal changes in condition and disease prevalence at times when caribou are normally harvested. A total of 52 caribou were tested for both grossly visible and subclinical conditions. The animals collected were generally very healthy, with a low prevalence of diseases and parasites. As in the community-based monitoring, primarily "naturally occurring" conditions were noted. The most common diseases and parasites detected and their seasonal prevalence are listed in Table 1.

Overall, both the type and relative prevalence of diseases and parasites detected were generally comparable between the community-based monitoring program and the systematic disease survey. While the current sample size from the community-based monitoring program is insufficient to statistically compare the two systems, this should be possible once more hunter-submitted samples have been tested. The one major discrepancy between the two monitoring systems occurred in the detection of the few diseases or parasites that do not produce grossly visible lesions consistently in infected animals. This was particularly evident with the parasite *Sarcocystis*, which has a very high prevalence in the population but only occasionally produces clinical signs in caribou that are visible to hunters. Overall, however, these preliminary results are encouraging for the use of a community-based monitoring system for the detection of grossly visible conditions. This type of system appears to have promise as a local, effective method of monitoring abnormalities in wildlife.

Expected Project Completion Date: Phase 1 of the project (i.e. project development, resource material production, training components) will be completed by March 31, 2000; Phase 2 (i.e. ongoing community monitoring) will continue through 2002/2003.

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METAL AND RADIONUCLIDE ACCUMULATION AND EFFECTS IN CARIBOU *(Rangifer tarandus)*

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OBJECTIVES

1. To verify high levels of metals (cadmium, aluminum, manganese) and radionuclides (lead-210 (^{210}Pb) and polonium-210 (^{210}Po)) detected in previous studies in caribou.
2. To assess biological effects by: (i) assaying tissues for evidence of chromosomal damage due to metal and radiation exposure; and (ii) monitoring histological and urinary markers of kidney damage and contaminant exposure.
3. To analyse several tissues for a range of elements and isotopes (uranium, thorium, stable strontium, titanium) which may provide insight into the source of contamination.
4. To contribute information on temporal trends in contaminant exposure in the mainland Bluenose caribou herd and the Lake Harbour herd near Kimmirut on south Baffin Island.

DESCRIPTION

Barren-ground caribou (*Rangifer tarandus groenlandicus*) are found across the Northwest Territories, and are a major component of the traditional diet in northern communities. Many factors can influence the individual and population health of caribou, and changes are often multifactorial in origin. Contaminants are one group of stressors which may influence the health status of a herd by altering tissue structure and function, and by acting in association with other stresses to impair reproduction, immune function or other body functions. The need for work on the biological effects of contaminants in caribou was highlighted by the results of earlier studies (Elkin and Bethke 1995, Macdonald *et al.* 1996) which showed elevated levels of metals and radionuclides in some caribou herds. The concentrations of metals (cadmium) and naturally occurring radionuclides (^{210}Pb and ^{210}Po) in the Lake Harbour herd near Kimmirut on south Baffin Island have been shown to be higher than other herds in the central and western Arctic (Gamberg and Scheuhammer 1994, Elkin and Bethke 1995, Macdonald *et al.* 1996)

The potential biological and ecological effects of these higher tissue loads of metals and radionuclides remain largely unknown. The current state of knowledge on animal adaptation to naturally occurring metals and nuclides is very limited. Cadmium (Cd) is known to disrupt kidney function and reduce the kidneys' ability to retain low molecular wight proteins and carbohydrates (CEPA 1994). A critical tissue concentration of 30 mg·kg^{-1} in kidney has been recommended for mammals (CEPA 1994, Outridge *et al.* 1994). Elkin and Bethke (1995) reported a mean cadmium concentration in kidney of 32 mg·kg^{-1} wet weight at Kimmirut, indicating that animals from this herd may exceed the tissue residue guidelines. Urinary β2 microglobulin and urea/creatinine analysis offers a way to examine possible kidney damage due to Cd exposure.

The radionuclide levels in caribou are notable because the resulting doses to the animals are significantly higher than background doses (Thomas 1994) and may be approaching levels in some individuals in which biological responses may occur (Amiro and Zach 1993). Radionuclides generally cause effects to the blood-forming or hemopoietic system (bone marrow, spleen and blood). Radionuclides are also known to cause single- and double-strand breaks in DNA and may produce high levels of variation in genetic structure, although doses required to cause these effects are relatively high (i.e. in excess of 500 mGy·y^{-1}). The major contributor to the dose in the Lake Harbour herd is alpha-emitter ^{210}Po, a nuclide which is known to accumulate on the endosteal (inner) surface of the bone in caribou (Salmon *et al.* 1995). This results in slightly higher doses to marrow than expected from deposition in the matrix of the bone. Metals such as chromium and nickel are also known to produce genotoxic effects and may add

Table 1. Morphometric measurements for female caribou collected at Kugluktuk in March 1998. Tissues from each animal were analysed for metals, radionuclides, indicators of kidney function and genetic analysis. NR - not recorded.

Sample ID	Sex	Body Dressed Weight (kg)	Body Length (cm)	Chest Girth (cm)	Back Fat Thickness (mm)
K9802	Female	41.7	163	130	15
K9803	Female	38.6	176	110	18
K9805	Female	NR	173	118.5	18
K9812	Female	36.3	165.5	116	0
K9813	Female	NR	178.5	123.5	NR
K9814	Female	NR	150	104	Trace
K9815	Female	NR	170.5	119.5	10
K9818	Female	NR	162	107	Trace
K9820	Female	NR	152.5	112	0
K9821	Female	NR	166	105.6	0
K9827	Female	NR	170	117	3
K9830	Female	NR	142	110.5	1

to the damage to genetic material caused by radiation.

This study will conduct a range of biological tests on tissue of caribou from two herds to determine if there are differences in the tissue function which can be related to known chemical stressors. The study will also confirm earlier results of elevated levels of radionuclides and metals in the Kimmirut herd. The biological tests will include the histological examination of kidney, in addition to tests of kidney function, and measurement of metallothionein levels in relation to metals such as cadmium and mercury. The study will provide an overall assessment of the health of the caribou in the two herds relative to the amount of metals and radionuclides present and develop hypotheses regarding the potential effects of exposure in the more highly exposed herd.

ACTIVITIES IN 1998/99

Field Sampling

In 1997/98, field collections were conducted in cooperation with the Kugluktuk Hunters' and Trappers' Organization, utilizing local hunters in planning and conducting the field work. Twenty caribou were collected from the Bluenose caribou herd at Hope Lake, approximately 100 km south of Kugluktuk, in March 1998. Sex, body condition and other biological and morphometric data were collected (Table 1), and a central incisor removed for aging by cementum analysis. Liver, kidney, muscle and bone samples were collected for metal and radionuclide analysis. Blood (buffy coat), spleen and bone marrow were collected for genetic analysis. Urine samples were collected from most animals for urinary β2 microglobulin and urea/creatinine. Blood and tissue samples were collected for general health and disease assessment. Upon completion of the field collection, the caribou meat from the collection was provided to the community for local use.

Twenty caribou were collected in March 1999 from the Lake Harbour herd. The same set of samples that were collected from the Bluenose caribou herd in 1998 (i.e. liver, kidney, urine, blood and spleen) were collected from the Lake Harbour herd and have been submitted for analysis.

Metals were analysed by ICP/MS, following digestion with nitric acid, by Envirotest Laboratories in Edmonton, AB. These laboratories are CAEAL accredited. QA/QC of the analyses included blanks, spiked samples, reference materials (DORT) and duplicates. A detailed description of the radionuclide analysis is given in Macdonald *et al.* (1996). Gamma-emitting radionuclides (^{137}Cs, ^{40}K, ^{226}Ra, ^{210}Pb, ^{232}Th) were analysed using a p-type well detector in tissue ashed at approximately 500°C. Polonium-210 was analysed by alpha spectrometry using a ^{209}Po tracer, after plating onto silver discs. The ^{210}Po concentration at the time of sampling was calculated as the sum of the supported fraction (^{210}Pb concentration) and the unsupported fraction, corrected for decay from counting date to plating date. QA/QC procedures included the use of standard radiation sources, duplicates and blanks.

RESULTS

Metal concentrations in the Kugluktuk caribou are reported in Table 2. Eight metals, listed in Table 2 with the detection limits, were below detection limits in all samples. The results closely correspond with other surveys of metal levels in caribou and indicate that metals with known effects in mammals (i.e. Hg and Cd) are relatively low in this herd relative to herds in the Yukon and in western NWT. These data confirm the use of this herd for comparison to the Lake Harbour herd which had high levels of both metals and radionuclides in the 1992 survey (Elkin and Bethke 1995). Tissues from the Kimmirut herd are presently being analysed.

The concentrations of radionuclides (Table 3) in the tissues of the Bluenose herd are very close to the levels reported by Macdonald *et al.* (1996) for the same herd in 1993. The highest dose to the animals is from the naturally occurring ^{210}Po, which ranges from mean values (± standard deviation) of 145 ± 99.3 Bq·kg^{-1} in bone to 290 ± 76.4 Bq·kg^{-1} in liver. These levels are much lower than those in the Lake Harbour herd in 1993. The ^{137}Cs concentration is highest in the kidney but, overall, the concentration is much lower than in central and eastern Arctic herds. This herd was chosen for comparison with the Lake Harbour herd because the previous survey indicated relatively low levels of radionuclides in this herd and these data support this conclusion.

Analysis for indicators of kidney function and histological examination of kidney tissue from tissues in the two herds is ongoing. Similarly, kidney tissue is being analysed for metallothionein, in relation to metal levels from the two herds. Samples of spleen, marrow and the blood buffy coat were collected from both herds and stored at Texas A&M (Dr. John Bickham) in –80°C freezers and are presently being analysed by flow cytometric analysis under blind conditions. The technique has been used successfully to show increased genetic damage in mammals at sites with mixed wastes in the US, and in birds and turtles exposed to radiation at sites contaminated with radionuclides. Depending on the availability of tissue, other population indicators used for indicating genetic damage will also be analysed in the three tissues from the two herds. The data and statistical analyses of these tests will be available by March 2000.

Table 2. The mean concentration of metallic elements in caribou tissues in the Bluenose herd near Kugluktuk, Nunavut collected in March 1998. The same tissues were collected from the Lake Harbour herd in March 1999 for comparison. The following metals were below detection limits (in brackets) in all samples: antimony (0.04 $mg \cdot kg^{-1}$ dry weight (wt.)), arsenic (0.2 $mg \cdot kg^{-1}$ dry wt.), beryllium (0.2 $mg \cdot kg^{-1}$ dry wt.), boron (2 $mg \cdot kg^{-1}$ dry wt.), chromium (0.2 $mg \cdot kg^{-1}$ dry wt.), thallium (0.04 $mg \cdot kg^{-1}$ dry wt.), vanadium (0.2 $mg \cdot kg^{-1}$ dry wt.). NA - not analysed.

	Liver		Kidney		Spleen		Bone	
Metal	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Al	0.83	0.13	0.85	0.12	0.96	0.48	24.60	35.51
Ba	0.24	0.10	1.09	0.49	0.73	0.42	347.80	53.39
Cd	1.04	0.54	4.03	3.37	< 0.08		< 2	
Ca	40.2	6.4	123.0	58.1	48.40	7.09	218000	6285
Co	0.07	0.03	< 0.08		< 0.08		<2	
Cu	42.5	17.0	4.99	1.69	0.70	0.07	<2	
Fe	362	176	49	13	154	21	809	69
Pb	0.13	0.06	0.07	0.02	< 0.04		<0.8	
Mg	191	11	170	13	150	20	3926.0	331.7
Mn	5.48	0.72	2.71	0.93	0.24	0.03	0.90	0.29
Mo	0.64	0.14	0.11	0.05	< 0.04		<0.8	
Ni	< 0.08		< 0.08		< 0.08		8.60	2.51
P	5632	458	3953	569	2702	613	115600	8019
K	3044	147	2784	307	3398	273	231	23
Se	0.28	0.05	0.67	0.21	< 0.2		<4	
Ag	0.13	0.10	< 0.08		< 0.08		<2	
Na	656	75	1341	115	998	165	5502	280
Sr	< 0.04		< 0.04		< 0.04		69.48	6.46
Sn	3.46	0.34	3.74	0.28	3.63	0.34	3.00	0.00
Zn	32	6	23.19	5.83	29.54	2.41	91.00	5.83
Hg	0.15	0.05	0.47	0.23	NA		NA	

Table 3. Radionuclide concentrations (Bq·kg^{-1} wet weight) in kidney, liver and a subset of bone samples as determined by gamma and alpha spectrometry (^{210}Po).

Sample ID	Fraction Dry wt.	Fraction Ash wt.	^{40}K	^{137}Cs	^{210}Pb	^{232}Th	^{226}Ra	^{210}Po
KIDNEY								
K9802-K	0.22	0.81	163	61	50	< 2	< 2	166
K9803-K	0.22	0.74	176	60	55	< 1	< 1	187
K9805-K	0.22	1.06	153	72	37	0.66	< 1	165
K9812-K	0.20	0.72	169	68	44	< 2	< 1	266
K9813-K	0.24	1.41	168	73	52	0.68	< 1	293
K9814-K	0.20	0.67	185	95	66	0.96	< 2	322
K9815-K	0.20	0.84	158	55	34	< 1	< 1	199
K9818-K	0.21	0.84	158	48	60	0.52	< 1	266
K9820-K	0.20	0.81	147	70	40	< 2	< 1	287
K9821-K	0.24	0.94	190	147	62	1.33	0.91	249
K9827-K	0.19	0.74	171	283	86	< 2	< 1	181
K9830-K	0.23	0.88	196	159	90	< 2	< 1	286
Average	**0.21**	**0.87**	**170**	**99**	**56**	**< 2**	**< 1**	**239**
St. Dev.	**0.02**	**0.20**	**15**	**68**	**18**			**55.9**
LIVER								
K9802-L	0.29	1.84	147	22.1	87	0.38	< 0.5	213
K9803-L	0.31	1.80	153	20.7	230	< 0.5	< 0.5	448
K9805-L	0.31	1.37	173	27.1	97	< 0.5	< 0.5	237
K9812-L	0.30	1.39	187	34.7	79	0.32	< 0.5	226
K9813-L	0.30	1.77	149	24.9	84	0.25	< 0.5	207
K9814-L	0.31	1.31	195	51.4	99	0.41	< 0.5	284
K9815-L	0.31	1.46	190	23.5	155	0.32	0.30	303
K9818-L	0.31	1.34	175	25.1	102	0.41	< 0.5	257
K9820-L	0.29	1.44	202	38.4	102	0.33	< 0.5	258
K9821-L	0.28	1.21	174	61.7	100	0.32	< 0.5	366
K9827-L	0.29	1.41	181	128.6	135	< 1	< 1	289
K9830-L	0.31	1.29	191	60.6	149	0.93	0.47	397
Average	**0.30**	**1.47**	**176**	**43**	**118**	**0.39**	**< 0.5**	**290**
St. Dev.	**0.01**	**0.21**	**18**	**31**	**43**	**0.19**		**76.4**
BONE								
K9802	0.89	32.38	< 0.7	2.6	552	5.2	5.8	151
K9805	0.89	29.70	< 0.7		544	5.8	9.7	227
K9812	0.86	33.51	< 0.7	3.1	501	4.9	14.8	138
K9813	0.89	40.48	143	2.6	667	9.1	20.8	353
K9814	0.87	38.97	< 0.7	4.9	438	10.4	19.0	160
K9815	0.89	28.89	< 0.7		499	8.4	6.5	30
K9821	0.87	33.67	36	4.3	512	4.3	16.4	38
K9827	0.88	32.94	< 0.7	8.2	619	9.4	11.9	128
K9830	0.88	30.95	18	5.1	525	5.1	12.7	83
Average	**0.88**	**33.50**	**< 0.7**	**4.38**	**540**	**6.95**	**13.05**	**145**
St. Dev.	**0.01**	**3.91**		**1.97**	**68**	**2.35**	**5.22**	**99.3**

DISCUSSION

The first phase of this project, which included the collection and analyse of tissues from the Bluenose herd near Kugluktuk has been completed, although the detailed analysis of tissues for indicators of biological effects is ongoing. Tissues were collected from the Lake Harbour herd in 1999 and are currently being analysed. The project is expected to be completed by March 2000. Most analyses are being conducted for both herds at the same time and will be available for reporting in 2000/2001.

Expected Project Completion Date: March 2000.

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AN INVESTIGATION OF FACTORS AFFECTING HIGH MERCURY CONCENTRATIONS IN PREDATORY FISH IN THE MACKENZIE RIVER BASIN

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OBJECTIVES

Long-term

1. To conduct limnological studies to determine why predatory fish inhabiting some lakes in the Mackenzie River Basin have elevated mercury levels while fish in other, apparently similar lakes, have lower mercury levels.
2. To determine the degree to which mercury flux rates have increased in high and low mercury lakes; to determine whether mercury flux lakes are higher in lakes in which fish have high mercury body burdens than in lakes in which fish have lower mercury body burdens.
3. To investigate whether it is possible to develop lake-specific remedial actions to reduce mercury concentrations in harvested fish from high-mercury lakes.
4. As part of the mercury studies, to conduct limited determinations of persistent organochlorine pollutants (POPs) concentrations in predatory fish to assess whether contaminant levels are below human health consumption guidelines. This POPs study also would allow us to compare mercury and organochlorine biomagnification rates.

Short-term

1. To investigate the basic limnology of Cli and Little Doctor Lakes, two high- mercury lakes, to provide insight into the environmental factors potentially affecting mercury sources to the lake and subsequent bioavailability within the lake.
2. To determine historic patterns in mercury flux rates to Cli Lake sediments through sediment coring studies.

DESCRIPTION

Fish are an important natural resource for communities living in the Mackenzie River Valley. Fish have and will continue to be important in subsistence fisheries and in maintaining cultural values in the North (Evans and Carpenter 1997). Moreover, there is a growing interest in the increased use of fish for commercial purposes, both for domestic sale and for the further development of tourist-based sport fisheries. For these reasons, the Department of Fisheries and Oceans (DFO) has been working with communities in conducting stock assessment studies. Stock assessment studies are designed to provide some indication of the capacity of the fisheries population to withstand continued and/or increased harvesting pressures.

Mercury levels have routinely been determined in fish as part of the DFO Inspection Service program (Jensen *et al.* 1997). These studies have revealed that there are large spatial variations in mercury concentrations in predatory fish in the NWT, particularly in the Mackenzie River Basin. Moreover, in many instances, mercury levels exceed both the 0.2 $\mu g \cdot g^{-1}$ recommended guideline for frequent consumers of fish and 0.5 $\mu g \cdot g^{-1}$, the upper limit for the commercial sale of fish. For example, mercury levels are very high in predatory fish inhabiting Cli Lake, Little Doctor Lake, Lac à Jacques, Turton Lake, and Lac Ste. Thérèse (L. Lockhart, unpublished data). Mercury levels reach 1.5 $\mu g \cdot g^{-1}$ in pike and walleye from Little Doctor Lake and 3-4 $\mu g \cdot g^{-1}$ in lake trout from Cli Lake. Mercury levels are lower than in other lakes such as Lac Belot where lake trout typically have concentrations below 0.2 $\mu g \cdot g^{-1}$ and Great Bear where pike and lake trout typically have mercury concentrations less than 0.7 $\mu g \cdot g^{-1}$. It is not known why mercury levels are very high in predatory fish inhabiting some lakes but not in other lakes. As a consequence, it is not known what actions can be taken to reduce environmental concerns related to mercury (and possibly to other metals) in the environment.

The Northern Contaminants Program (NCP) has recognized that high lake-to-lake variability in levels of mercury and POPs in fish has not been adequately explained. Furthermore, the NCP has identified the need for detailed studies of mercury biomagnification in predatory fish at select study sites. Accordingly, in 1998/1999, we began a new project investigating why predatory fish in some lakes in the Mackenzie River Basin have very high concentrations of mercury in their tissue while fish in other lakes have low mercury concentrations. This project is linked with Lockhart and Evans' NCP project "Mercury in fish from surveys in lakes in the western Northwest Territories" and builds upon previous understanding gained in contaminant biomagnification in Great Slave Lake and elsewhere (Evans 1997, Evans *et al.* 1996, 1998, Kidd *et al.* 1995). Furthermore, because these lakes are largely unstudied, our study is obtaining fundamental information on the limnology and fisheries of selected high-mercury and low-mercury lakes.

The study began with a focussed research effort on Cli Lake (Figure 1), west of Fort Simpson and in the Nahanni Mountain Range; Little Doctor Lake was the subject of less intensive effort. Cli Lake was selected for focussed study because mercury levels are very high in lake trout muscle (Figure 2), human health advisories have been issued regarding the consumption of lake trout from the lake, and because a community member, Loyal Letcher, has constructed a naturalist lodge on the lake. From a community viewpoint, there has been a significant financial investment in Cli Lake, including a tourist-based sport fishery. From a scientific viewpoint, there is sufficient infrastructure (boats, housing, electrical power, refrigerators and freezers) for conducting scientific studies. Mercury levels also are high in pike, walleye, and lake trout in Little Doctor Lake, a few kilometers to the south of Cli Lake; and human health advisories have been issued regarding the consumption of walleye and pike from Little Doctor Lake. Little Doctor Lake has unusually red waters, making it an ideal candidate for investigating the influence of water colour on mercury levels in predatory fish. While there is a lodge on the lake, it is more rustic with limited refrigeration and freezer capacity and no electrical power.

Both Cli and Little Doctor Lake are nestled in the Nahanni Mountain Range to the west, with flatter plains to the east. Both lakes overlie a major fault line. It has been hypothesized that increased flux rates of mercury to modern sediments are, in fact, related to mercury release and migration from deeper sediments, especially along fault lines. There are numerous small creeks flowing into Cli Lake while Little Doctor Lake is fed primarily by the Sibbeston River which, in turn, drains Sibbeston Lake. Both lakes outflow through the west through a small embayment on the western side on the Nahanni Mountains. As would be expected, the scenery is spectacular and the tourist-based potential for both lakes is immense. Thus, the lakes are likely to experience increased development and human impact in the upcoming years.

ACTIVITIES IN 1998/99

Field sampling was delayed until September due to delays in funding decisions. This posed some difficulties because the weather had begun to deteriorate. With the onset of autumn, there had been a major die-off in aquatic plant growth and some nearshore forage fish may have moved into deeper waters. Nevertheless, the trip was successful and a great deal was accomplished. Baseline sampling effort focussed on determining: the overall features of the bathymetry of Cli and Little Doctor lakes; the major features of their shorelines, including the presence of shallow, weedy areas; water column measurements of temperature, oxygen, pH, particulates, plant nutrients, and chlorophyll; zooplankton and benthic collections (Cli Lake) to assess composition and standing stocks; and preliminary test netting in Cli Lake to determine whether walleye, pike, and cisco were present. Major inflowing streams were sampled in Cli Lake for temperature, pH, mercury concentrations in filtered water: sediments were sampled for mercury and other metals. The open waters of Cli Lake (water) and its outflow (water and sediments) also were sampled for mercury. In Little Doctor Lake, the open lake (water only) and Sibbeston River (water and sediments) were sampled for mercury. Benthic organisms were collected in the Sibbeston River for mercury analyses along with various species of fish from Cli Lake.

Sufficient funds remained in the account to conduct a winter coring study in Cli Lake. Sediment cores were collected at two sites to determine background mercury flux rates and the degree to which flux rates had increased in recent years. Insufficient remaining funds, compounded with various difficulties encountered while on site, precluded sampling Little Doctor Lake. Snow samples were collected at several sites and analyzed for mercury. Water was collected from the lake and from one stream and then analysed for mercury. Limnological sampling was conducted at the deep-water lake site.

RESULTS

In brief, the following were learned during the September sampling:

Cli Lake has a maximum depth of 89 m and is relatively smooth-bottomed and steep- sided. Suitable locations for winter coring studies were identified. Cli Lake probably is not very productive because of its depth. The shoreline is very rocky with cobble extending out to 5 m in most locations. Macrophyte growth appears to be significant in some protected locations although much of the nearshore was steep-sided, rocky, and exposed. These shallow weedy areas probably provide good pike habitat. Because Cli Lake is a clear-water lake, walleye, if present, may be present in deeper areas offshore of the weed beds. Little Doctor Lake is deeper than Cli

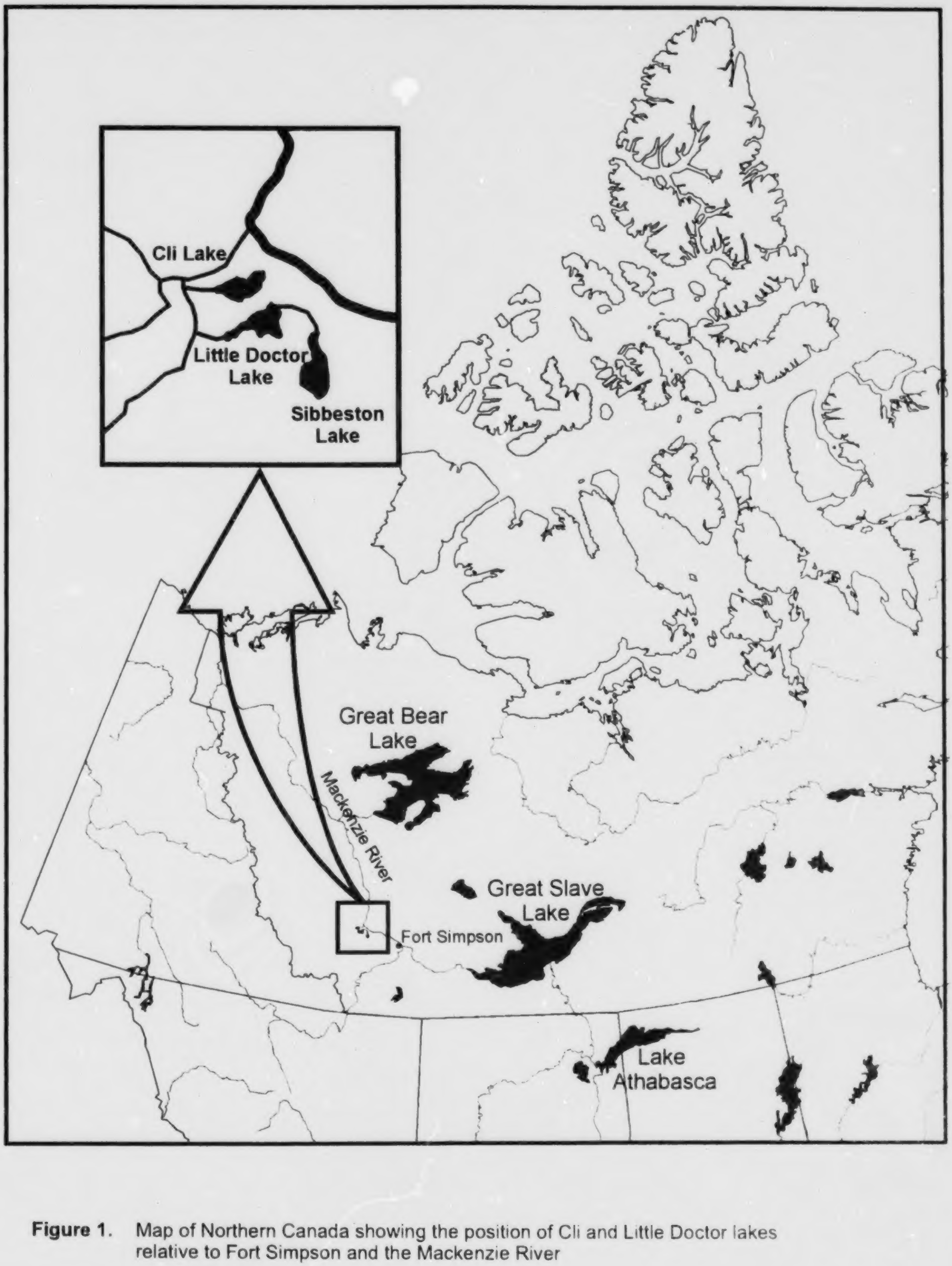
Cli Lake
Little Doctor Lake
Sibbeston Lake
Great Bear Lake
Mackenzie River
Great Slave Lake
Fort Simpson
Lake Athabasca

Figure 1. Map of Northern Canada showing the position of Cli and Little Doctor lakes relative to Fort Simpson and the Mackenzie River

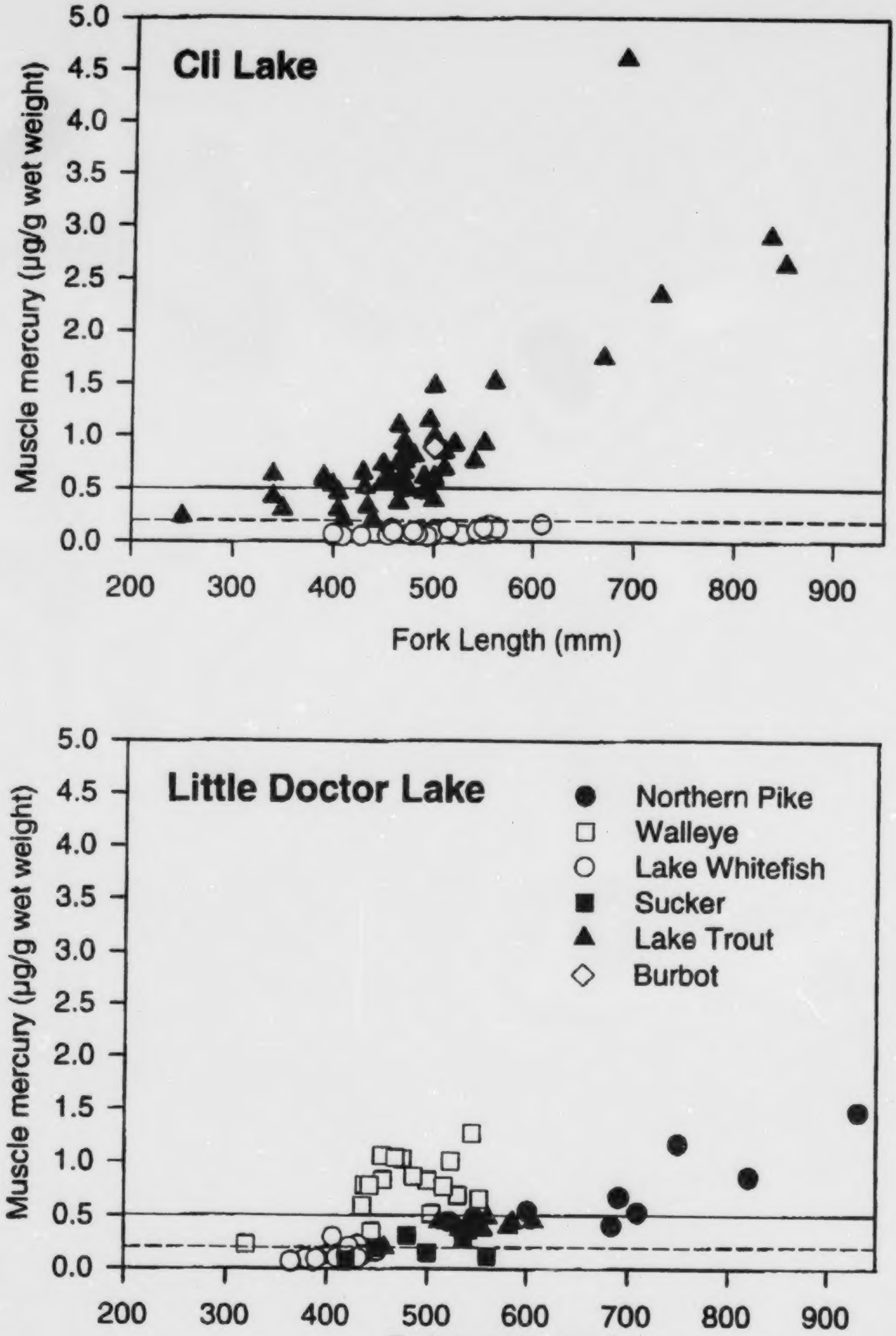

Figure 2. Muscle mercury concentration in different species and varying lengths of fish from Cli Lake and Little Doctor Lake.

Lake with a maximum depth of 170 m and a more irregular lake bottom. Water level apparently fluctuates less than 1 m over the year (R. Tetso, pers. comm.).

Cli Lake is slightly basic (pH 7.7-8.3), well-oxygenated, and low in plant nutrients (TP = 5 $\mu g \cdot g^{-1}$). Dissolved organic carbon concentrations average 4.2 $mg \cdot L^{-1}$. Secchi disc depth was 7.3 m. Little Doctor Lake is less alkaline (pH 7.5-7.9) than Cli Lake. Little Doctor Lake is remarkable in that the water is a clear, red-brown (tea) colour throughout its length and width. As a consequence of its pronounced red-brown colour, light penetration is lower than in Cli Lake with a Secchi disc depth of only 2.8 m. Phosphorus concentrations were higher (TP = 15-20 $\mu g \cdot g^{-1}$) than in Cli Lake as were dissolved organic carbon concentrations (average = 12.5 $mg \cdot L^{-1}$). The water column was well-oxygenated in both lakes.

In Cli Lake, zooplankton were dominated by copepods with low numbers of cladocerans and mysids; algal biomass was low (chlorophyll 1.0 $\mu g \cdot g^{-1}$). Benthos were very sparse, particularly in deep waters and shallow sandy sites. Algal biomass in Little Doctor Lake also was low (chlorophyll 1.3 $\mu g \cdot g^{-1}$). Zooplankton composition was similar to that in Cli Lake. However, mysids appeared to be in greater abundance than in the Cli Lake tows. Furthermore, a widespread scattering layer was noted at approximately 10 m on the depth sounder charter recorder. This layer is believed to be zooplankton. Such a layer was not present in the clearer waters of Cli Lake.

Gill nets were set twice in Cli Lake. Pike were caught in the shallow embayment at the Cli Lake outflow. In addition, many small coregonids (<10 cm) were captured in the finer meshes of the net. We have not yet determined whether these small fish are immature whitefish or cisco. Since cisco have not yet been caught in the lake we suspect that these immature fish may be whitefish. All fish are being analysed for mercury, arsenic, selenium, cadmium, and stable isotopes. Walleye were not captured and are believed to be absent from the lake (L. Letcher, pers. comm.)

There are many creeks flowing into Cli Lake from markedly different drainage basins. Nine creeks had significant inflows and were measured for temperature, conductivity, and pH (Table 1). Streams to the east of the lake were more coloured and had lower conductivity (118-175 $\mu S \cdot cm^{-1}$) than the streams flowing down the mountains (conductivity = 563-602 $\mu S \cdot cm^{-1}$). Many mountain streams were dry but have major inflows during spring. Mercury concentrations in filtered water were very high and have a high probability of being suspect: thus, they are not being presented in this report. Interestingly, highest values were in Cli Lake streams located near the fault line running under Cli Lake, in one inflowing stream at the eastern end of Cli Lake, and in the Sibbeston River. Lowest values were in Cli Lake. Mercury concentrations in stream and lake sediments were not unusually high (Table 1). There was no obvious relationship between mercury concentration in stream sediments and stream pH and conductivity. Other chemical analyses of stream and lake sediments are ongoing as are analyses of biological samples.

The March 1999 sampling trip was generally successful. A single sediment core was collected in the deepest region of the lake (85 m) and a second towards the east in 63 m of water. Sediments were sticky clays and not readily penetrated by the corer. As a consequence, both cores were short (< 15 cm).

Snow samples were collected at several sites around the lake. Sites were near forested areas and defined as shallow depth, medium depth, and very deep with respect to snow thickness. Mercury concentrations in snow were low and typical of values observed in other similar regions in the Northwest Territories (Table 2). There was no obvious difference in concentrations among study sites. Water samples were collected from three depths in Cli Lake (85 m station). Mercury concentrations were substantially lower in lake waters than in snow. There was a weak trend for concentration to decrease with depth. A single stream, running down the mountain to the east of the lodge also, was sampled. Mercury concentrations were slightly higher than in the lake but substantially lower than in the snow. This suggests that stream flow was dominated by ice melt rather than snow melt.

The lake was weakly stratified with water just under the ice near 0 °C, increasing to 3.5 °C at 84 m depth. The water column was well oxygenated with 70% saturation at 84 m depth. Nutrient concentrations remained low.

We have been seeking to build strong community interactions. We contacted the Métis, Liidli Koe First Nation, and Mayors' offices prior to each field trip, and conducted office visits while in Fort Simpson for both sampling trips. Following the September trip, we provided letters summarizing accomplishments of the study to all three offices as well as follow-up telephone calls. Community members have been very helpful sharing their knowledge of these lake ecosystems and suggesting other lakes which could merit comparative study in future years.

DISCUSSION/CONCLUSIONS

Studies in September 1998 have provided us with baseline data on the general limnological features of Cli and Little Doctor lakes. These data complement fish data (lengths, weights, sex, mercury levels) collected by DFO

Table 1. Physical-chemical properties of stream waters and mercury concentrations in stream and lake sediments, Cli and Little Doctor lakes. September 1998 sampling.

Stream	Temperature C˚	pH	Conductivity µS/cm	Hg ng/gm	Notes
Cli Lake outflow	8.3	8.3	221	23	Green water. Lots of macrophytes
Stream 2	4.8	7.9	563	45	Slow flowing
15 m depth offshore of Stream 2	–	–	–	46	Coarse woody material in sediments
Stream 3	4.6	8.2	602	63	Muddy water
Stream 4	4.0	7.7	553	<4	Woody debris and coarse sands
Stream 5	4.6	7.1	553	<4	Mouth dried up
5 m depth offshore of Stream 5	–	–	–	57	
10 m depth offshore of Stream 5	–	–	–	59	
Stream 6	3.6	7.3	118	105	Small boggy creek
5 m depth offshore of Stream 6	–	–	–	38	
10 m depth offshore of Stream	–	–	–	20	
Stream 7	8.0	8.0	175	8	Brown water creek. Slow flow
Stream 8	7.9	7.9	245	9	Not as brown as Stream 8
Stream 9	8.0	8.0	265	23	Light brown water
5 m depth offshore of Stream 9	–	–	–	84	Coarse sand, pond weed debris
Stream 10	8.3	8.3	242	23	Light brown
Stream 12	7.7	7.7	309	81	Slow flowing
Sibbeston River	13.0	8.0	172	9	

Table 2. Mercury concentrations (ng·L^{-1}) in water and snow, Cli Lake. March 1999 sampling trip. Data are expressed as means ± standard deviation

Site	Sample size (n)	Mercury concentration
Water		
Cli Lake 5 m	3	0.36 ± 0.19
Cli Lake 40 m	1	0.28
Cli Lake 75 m	3	0.24 ± 0.04
Creek to east of lodge	3	0.42 ± 0.05
Snow		
Forested region, shallow sites	4	3.24 ± 2.30
Forested region, medium sites	4	3.35 ± 1.23
Forested region, deep sites	3	2.53 ± 0.38
Lake, offshore	3	3.95 ± 2.01

as part of the March 1996 stock assessment studies in both lakes. Several initial hypotheses which we had regarding the possible factors affecting elevated mercury levels in Cli and little Doctor Lake no longer appear as attractive as initially thought.

While Cli and Little Doctor lakes possess shallow, protected areas where macrophyte growth appears significant in summer, these beds do not appear to be an extensive feature of either lake. Thus, elevated mercury levels do not appear to be associated with extensive wetlands within these lakes. Nor do elevated mercury levels appear to be associated with the size of the drainage basin. Mercury levels are higher in lake trout from Cli Lake than in Little Doctor Lake. Yet Cli Lake (surface area 43 km^2) has a much smaller watershed (196 km^2), with only 5 km^2 in wetlands versus the 796 km^2 of Little Doctor Lake (surface area 20 km^2), 100 km^2 of which is wetland (B. Garrett, Geological Survey of Canada, pers. comm.). If the Sibbeston Lake watershed is included, Little Doctor Lake has surface area of 1,724 km^2 of which 283 km^2 is wetland.

Water colour (humic stained versus clear water) also does not appear to be a primary factor in affecting spatial gradients in mercury concentrations in fish in the NWT. Little Doctor Lake is deeply stained while Cli Lake has clear waters: mercury concentrations are elevated in fish from both lakes.

It is noteworthy that both lakes are deep and support mysid populations. Food chain length is important in affecting mercury (and POPs such as PCB) biomagnification. However, we have not yet determined whether mysids are consumed directly by predatory fish such as lake trout or whether intermediate forage fish such as cisco are also part of the offshore food web. Mysids generally are a deep water invertebrate and are less likely to be important in the diets of pike (Little Doctor and Cli Lake) and walleye (Little Doctor Lake), fish that tend to inhabit shallow waters.

Atmospheric inputs of mercury also are unlikely to be the primary factor affecting elevated mercury levels in Cli and Little Doctor Lake. At present, we have no reason to hypothesize that atmospheric input rates are substantially greater in high mercury than low mercury lakes. Further investigation of watershed size relative to lake area, elevation of surrounding topography, etc., should help resolve these issues.

The hypothesis that elevated mercury levels in Cli and Little Doctor lakes are associated with mercury inputs along the fault line underlying the lake is intriguing and will be the subject of greater investigation in 1999/2000. However, even if this hypothesis is shown to have some validity for Cli and Little Doctor lakes, it cannot explain high mercury levels in other lakes in the NWT, i.e., Lac Ste. Thérèse and Lac à Jacques which do not lie along fault lines. In those instances, other factors such as shallow waters, extensive weed beds, a large drainage basin relative to lake size, and the presence of stained water may be more important causal factors.

Research effort in 1999/2000 will focus on investigations of mercury biomagnification in the Cli Lake food web and in comparative stream studies. Other researchers have noted marked spatial variations in mercury in biota inhabiting riverine ecosystems (Munn and Short 1997, Tremblay and Lucotte 1997); we will investigate whether this also occurs in the Cli Lake streams, especially those near and distant from the fault line. One and possibly two cores will be dated from Cli Lake. Mercury (and other metal) flux rates to the sediments will be compared with literature values of flux rates to sediments in other lakes in the NWT (Lockhart *et al.* 1995, 1998) and elsewhere to determine whether lakes with high mercury flux rates also are lakes in which predatory fish have high mercury concentrations. We also will assess whether background mercury fluxes to these lakes are higher than in lakes in which mercury levels in fish are lower. We suspect that much of the mercury is being mobilized in the watershed and entering the lake with runoff. Stream and lake sediments will be collected and rates and factors affecting mercury methylation and demethylation rates measured (Jackson 1989). A second coring trip may be conducted depending on the results of the analysis of the Cli Lake core. In later years, we may include measurements of mercury methylation rates and the role of light in the formation of dissolved gaseous mercury (Amyot *et al.* 1997). We believe that mercury may follow different pathways in Cli Lake, a relatively clear-water lake, than in Little Doctor, a highly-coloured lake. In addition, we may investigate possible remedial actions for reducing the high mercury levels in the predatory fish of Cli and Little Doctor lakes. Intense fishing effort has been proposed as one mechanism for reducing mercury levels in predatory fish (Verta 1990).

We also will return to our original objective of comparing mercury sources and pathways in low and high mercury (predatory fish) lakes. One candidate lake is Trout Lake, located southwest of Fort Simpson. Background studies have been conducted on the lake, determining that mercury levels are relatively low, averaging 0.10 $\mu g \cdot g^{-1}$ in pike, 0.11 $\mu g \cdot g^{-1}$ in burbot, 0.13 $\mu g \cdot g^{-1}$ in walleye, and 0.223 $\mu g \cdot g^{-1}$ in lake trout (Swyripa *et al.* 1993). There is a community and lodge at the lake as well as a winter road. Another possibility is Sibbeston Lake, at the headwaters of Little Doctor Lake, although this lake is only approximately 3 m deep and not a lake trout lake. We also could examine lakes to the east of the Mackenzie River, should community support be forthcoming.

Expected Project Completion Date: This study is expected to be completed in 2002/2003. This will enable us to complete our investigations of factors affecting high mercury levels in predatory fish in Cli and Little Doctor lakes, conduct comparative studies in lakes in which mercury levels are lower in predatory fish, and assess the potential for developing remedial actions to alleviate concerns related to elevated mercury levels.

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CONTAMINANTS IN YUKON MOOSE AND CARIBOU - 1998

Project Leader: Mary Gamberg, Gamberg Consulting, Whitehorse, YT

Project Team: Mark Palmer, Department of Indian Affairs and Northern Development (DIAND);
Department of Renewable Resources, Government of Yukon (YTG);
Yukon Conservation Society

OBJECTIVES

1. To develop baseline data on levels of inorganic contaminants in Yukon moose and caribou.
2. To identify potential health risks to First Nations and others using moose and caribou as a food source.
3. To identify potential health problems in wildlife populations as a result of contaminant loading.
4. To identify potential temporal and geographical trends in inorganic contaminants in Yukon moose and caribou.

DESCRIPTION

This project is part of the ongoing monitoring of contaminants in Yukon wildlife that started in 1992 with a study of the Finlayson caribou herd (Gamberg 1993), continued with a comprehensive look at contaminants in traditional/country foods (Gamberg, unpubl. data), and is now monitoring temporal trends using moose and caribou as key species (Gamberg 1997, 1998).

ACTIVITIES IN 1998/99

Yukon hunters were requested to submit kidney, liver, muscle and tooth samples from moose and caribou killed during the 1998 hunting season. The program was advertised through posters, radio, newspaper and local magazine ads, articles and interviews. Hunters were instructed to freeze individual samples separately in plastic bags as soon as possible and to submit them to their local Department of Renewable Resources office. Each hunter who submitted samples had his/her name entered into a draw, once for each tissue submitted. The draw was for a charter flight valuted at $1000. Hunters who submitted samples received a thank you letter, which also state the age of the animal (if a tooth was provided) and a description of the project. A brief background of cadmium in Yukon wildlife was included, as well as the consumption recommendations from Yukon Health and Social Services.

Samples were submitted from 114 moose, 84 caribou and 1 mule deer. Of these, all the moose and 40 caribou were contributed by hunters. Forty-three Porcupine caribou samples were provided by a YTG Renewable Resources biologist. Other samples were taken opportunistically by other Renewable Resources personnel, including kidney, liver and muscle tissue collected from six bison and 60 kidneys from the Porcupine caribou herd collected between 1994-1997.

Age was determined using incisors. Only entire kidneys submitted with a tooth were used for contaminant analysis, while liver and muscle sample were archived for possible future analysis. Samples were homogenized and analysed for 26 elements by Elemental Research Laboratories Inc. in Vancouver, BC, using the inductively coupled plasma with mass spectroscopy technique. Although data for all 26 elements are presented in the technical report for DIAND (Gamberg 1999), only seven elements of interest are discussed in this summary.

Relationships between year of collection, age of the animal and element concentration were tested using moose (1996-98) and Porcupine caribou (1991-98) data. Comparable arsenic and lead data for the Porcupine caribou were only available from 1994-98. Other species and other caribou herds were not analysed due to missing age information or insufficient sample size. Where possible, a general linear model was used to test the effect of year and age on the element of interest; when data were not normal, Spearman's Rank Correlation was used.

RESULTS AND DISCUSSION

Renal arsenic concentrations in bison were similar to those in moose, and in the single mule deer measured the concentration was somewhat lower (Table 1). In bison, arsenic levels were highest in kidney and lowest in muscle tissue. These levels fall within the range considered normal for domestic cattle (Puls 1994).

Table 1. Element concentrations (ppm dry weight) and moisture (%) in muscle (M), liver (L) and kidney (K) tissue from Yukon big game animals.

Species/ Caribou Herd	Tissue	Age (yr)	N	Moisture X	SD	As X	SD	Cd X	SD	Cu X	SD	Pb X	SD	Hg X	SD	Se X	SD	Zn X	SD
Bison	M		6	74.3	1.1	0.06	0.02	<0.01	0.0	7.6	2.6	0.04	0.02	<0.05	0.00	0.73	0.30	187	42
Bison	L		6	71.2	1.0	0.17	0.04	1.2	0.5	93.1	56.6	0.08	0.04	0.06	0.03	0.62	0.13	140	71
Bison	K		6	76.9	1.4	0.52	0.12	16.8	12.2	25.8	2.1	0.36	0.72	0.19	0.15	4.42	0.71	75	17
Moose	K	4.4	79	79.5	1.7	0.46	0.56	116.2	75.3	17.7	5.0	0.09	0.09	0.08	0.07	4.76	1.81	131	33
Mule Deer	K	5	1	81.2		0.16		11.1		17.9		0.07		0.71		5.00		83	
Caribou																			
Coal River	K	5	1	81.3		0.38		32.0		36.5		0.16		2.04		4.40		124	
Ethel Lake	K	4	1	77.3		0.32		48.5		20.9		0.10		1.17		7.60		119	
Finlayson	K	6	1	80.2		1.51		58.6		16.4		0.18		1.20		6.30		107	
Hart River	K	9	1	76.6		0.11		41.4		26.4		0.17		0.52		3.60		121	
Ibex	K	10	1	77.7		0.18		64.5		19.8		0.39		0.49		3.20		82	
Klaza	K	4	2	79.9	0.2	0.28	0.04	30.9	25.1	21.5	3.3	0.18	0.08	1.32	0.81	6.75	1.91	104	10
Pelly	K	9	1	78.0		0.16		174.0		24.5		0.12		0.64		3.10		149	
Porcupine	K	3	112	78.2	1.8	0.20	0.05	47.0	34.4	25.3	4.5	0.25	0.39	2.11	0.81	5.56	1.78	121	17
Rancheria	K	6	1	80.5		0.16		37.1		34.8		0.12		3.64		4.10		178	
Tay	K	3	4	79.3	0.8	0.20	0.12	48.8	13.4	26.5	2.7	0.21	0.13	1.16	0.98	11.50	2.75	118	3
Wolf Lake	K	3	2	77.7	3.2	0.16	0.15	34.3	9.2	31.3	1.8	0.19	0.01	1.79	0.66	7.30	2.26	122	21

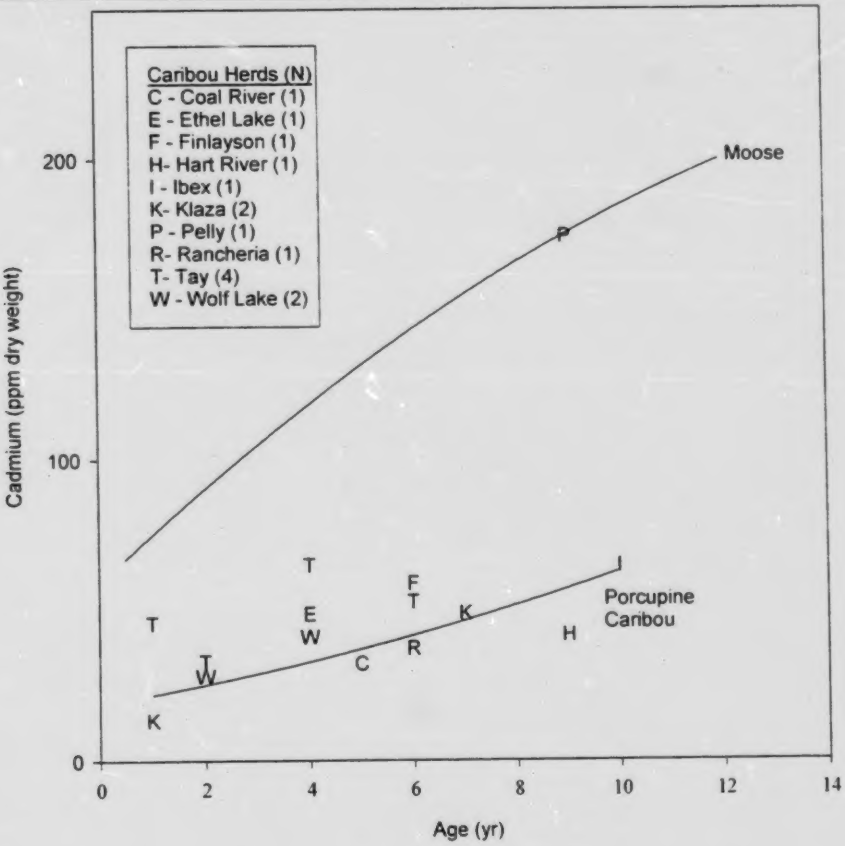

Figure 1. Cadmium concentrations in Yukon moose and caribou kidneys.

Consistent with the 1997 study (Gamberg 1998), moose had significantly higher renal cadmium concentrations than caribou measured in this study ($p<0.001$; Figure 1). The mule deer and bison had even lower kidney cadmium concentrations, and there was no detectable cadmium in bison muscle (Table 1). One exception to this was an individual caribou from the Pelly herd which can be seen directly on the regression line for moose in Figure 1. Two caribou from this herd were measured in 1997 (Gamberg 1998), a three-year-old that had cadmium levels almost as high as would be expected in moose, and a four-year-old which had a very low level of cadmium in its kidney. While it is difficult to draw conclusions from three animals, it is possible that the Pelly caribou herd has cadmium levels more similar to the higher levels found in the Finlayson and Tay herds (Gamberg, unpubl. data).

Renal cadmium concentrations in Yukon moose were higher than those found in moose from Ontario (Glooschenko *et al.* 1988). Previous work in the Yukon (Gamberg, unpubl. data) suggests that these high levels of cadmium are coming from natural areas of mineralization. In naturally acidic areas, cadmium is liberated from the soil to be absorbed by plants which are in turn consumed by herbivores. Some plants absorb more cadmium than others, willows (*Salix* sp.) being one of the most efficient (Crowder 1991). Because willows are a major portion of moose diets (Risenhoover 1989), Yukon moose would be expected to accumulate higher concentrations of cadmium in their kidneys (and livers) over their lifetimes than moose from areas with lower environmental levels of cadmium. Yukon Health and Social Services has recommended limiting human consumption of moose and caribou kidneys based on previously collected data. Because cadmium levels have not changed, these recommendations should still be relevant.

Although average renal cadmium for each species measured in this study is well below the critical threshold value (400-800 $\mu g \cdot g^{-1}$ dry weight (dry wt.)) at which renal tubule dysfunction has been shown to occur in various species (Elliot *et al.* 1992, Kjellstrom 1986), there are several individual moose from this study that have renal cadmium concentrations that do approach that level. Two nine-year-old moose from the southeastern part of the Yukon had 390 and 313 $\mu g \cdot g^{-1}$ cadmium (dry wt.) in their kidneys. This indicates potential for older moose in some parts of the Yukon to be at risk of renal dysfunction due to high renal cadmium. It is likely that areas in the Yukon that are geologically high in cadmium will be reflected by high levels of cadmium in moose (and potentially other animals as well). Currently, there is insufficient data to explore this geographic variation in any detail, and it would be impossible to sample enough moose in one year to do so adequately. By continuing the hunter survey, and combining data from a number of years, the database should eventually sufficiently represent the area, and geographical trends in moose cadmium levels can be investigated, furthering our understanding of cadmium in the Yukon environment.

Renal copper concentrations were generally higher in caribou and bison than moose and mule deer (Table 1). Renal copper in caribou and bison from this study fell within the marginal to adequate range for domestic cattle (Puls 1994), whereas concentrations in moose kidneys would be considered the low end of marginal. It is difficult to determine if there is a potential for copper deficiency in these moose as has been noted in Alaska (Flynn *et al.* 1977). Unfortunately, in the Alaskan study only hair, blood and hooves were examined, and comparing renal copper levels to these would be questionable.

Most renal lead concentrations in this study were <0.50 $\mu g \cdot g^{-1}$ and similar to lead levels found in NWT caribou (0.10 - 0.47 $\mu g \cdot g^{-1}$ dry wt.; Elkin and Bethke 1995). Hepatic and muscular lead concentrations in bison were even lower (Table 1). Only three animals (two caribou and one bison) had renal lead levels greater than this (4.1, 1.2 and 1.8 $\mu g \cdot g^{-1}$ respectively), and these were still well below the threshold level of 80 $\mu g \cdot g^{-1}$ that is thought to be indicative of lead poisoning (Scheuhammer 1991).

Mercury concentrations were generally higher in caribou than other species measured, and lowest in moose (Table 1), but all were low relative to those found in NWT caribou (2.76-14.14 $\mu g \cdot g^{-1}$ dry wt.; Elkin and Bethke 1995). Even the highest mercury level measured in this study, (4.96 $\mu g \cdot g^{-1}$ dry wt. or 1.08 $\mu g \cdot g^{-1}$ wet wt. in a Porcupine caribou) is far below the threshold level of 30 $\mu g \cdot g^{-1}$ wet wt. cited by Scheuhammer (1991) at which neurological effects might be expected to occur. Previous work in the Yukon (Gamberg, unpubl. data) has shown that methyl mercury concentrations in Porcupine caribou kidneys were below detection limits, indicating that the mercury present was in the less toxic form of inorganic mercury. Braune *et al.* (1991) suggested that high mercury levels in biota in the Canadian Arctic reflect naturally occurring geological sources rather than industrial pollution.

Average renal selenium in caribou ranged from 3.1-7.6 $\mu g \cdot g^{-1}$ dry wt., and mean values for moose, bison and mule deer were also within that range. This falls very close to the range considered adequate for deer (0.60-1.10 $\mu g \cdot g^{-1}$ wet wt. or 3.0-5.5 $\mu g \cdot g^{-1}$ dry wt.; Puls 1994). Hepatic and muscular selenium in bison were considerably lower.

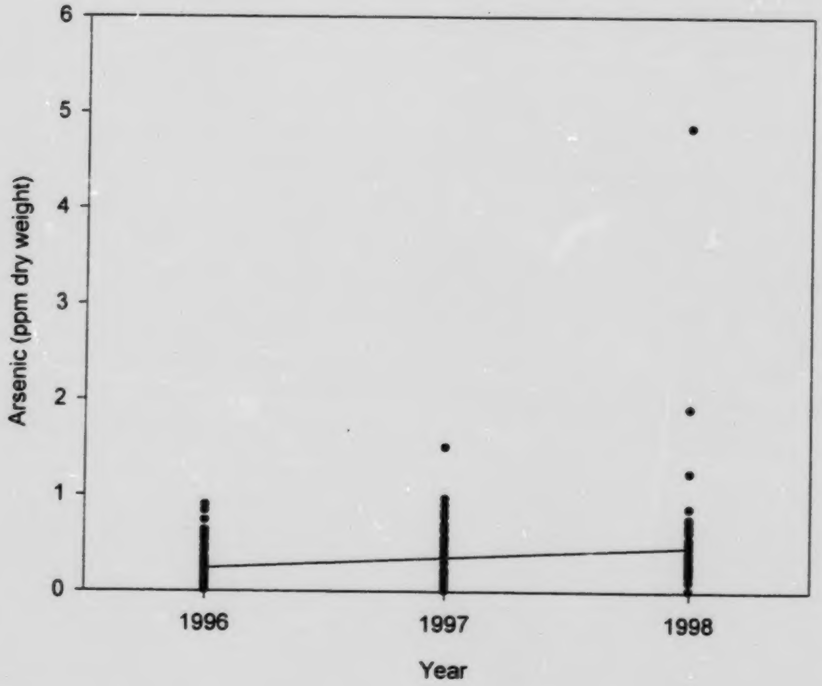

Figure 2. Arsenic concentrations in Yukon moose kidneys.

Renal zinc levels were fairly consistent among species, ranging from a mean of 75 $\mu g \cdot g^{-1}$ dry wt. in bison to 124 $\mu g \cdot g^{-1}$ dry wt. in an individual caribou from the Coal River herd (Table 1). Concentrations in caribou from this study are similar to those found in caribou from NWT (96.75 - 120.86 $\mu g \cdot g^{-1}$ dry wt.; Elkin and Bethke 1995).

Arsenic levels in moose kidneys from 1998 continued the upward trend seen in the 1997 study (Figure 2, Gamberg 1998). The increase in absolute amounts of arsenic is slight and not of concern from a toxicological point of view. In Porcupine caribou kidneys, selenium showed an increase while zinc showed a decrease over time when data from 1991-98 were analysed together. Again, the changes over time are small and not of concern. Monitoring these levels over the next few years will likely clarify these relationships.

Age was positively correlated with cadmium in moose and Porcupine caribou (Figure 1). This relationship has been extensively described in the literature (Brazil and Ferguson 1989, Crete *et al.* 1987, Crete *et al.* 1989, Froslie *et al.* 1986, Gamberg and Scheuhammer 1994, Glooschenko *et al.* 1988), and was expected in this study. Renal copper decreased with age in moose from this study, as it did in the 1997 study (Gamberg 1998). Analyzing 1998 data separately yielded the same results. Puls (1994) described the same relationship in deer, and since the decrease seen in this study is small, it should probably be considered normal. Mercury and selenium also decreased with age in moose, relationships not seen in the 1997 study. These two elements are strongly related physiologically, selenium having an ameliorating effect on the toxicity of mercury (Cuvin-Aralar and Furness 1991). A correlation between age and these elements is not commonly described in discussions of mercury and selenium toxicology in the literature. It is not clear why these relationships are evident in the 1998 data but not in previous data. Perhaps increasing the sample size over the next few years will shed some light on this issue.

CONCLUSIONS

Element concentrations of moose, caribou, bison and mule deer found in this study should be considered baseline levels. Yukon moose and some caribou showed higher renal cadmium concentrations than in the same species from other areas, and caribou had higher renal mercury levels than the other species studied. It is likely that both these contaminants are entering the food chain from natural mineralizations. There are insufficient data to explore geographical trends in the Yukon, but continued research in this area will allow these analyses in the future. Those concerned about the consumption of contaminants from wild game should refer to the health advisory issued by Yukon Health and Social Services (Whitehorse).

Project Completion Date: The project was completed in March, 1999.

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BASELINE STUDY OF CONTAMINANTS IN BAKER LAKE

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OBJECTIVES

1. To provide baseline data on organochlorines, metals (particularly mercury), and radionuclides in the Baker Lake environment, in order to evaluate wildlife and human exposure risks.
2. To communicate the results of the study to the Community and to address community contaminant concerns.
3. To provide a forum for communication to the community and the schools on contaminants issues.

DESCRIPTION

Baker Lake is a unique Inuit community in that the people rely on caribou and fish for a large portion of the diet and very little in terms of marine mammals. Although considerable work on contaminants in the Canadian North has been conducted over the last ten years, little has been conducted in the Baker Lake area. Isolated surveys of radionuclides in caribou and fish were generated from baseline studies for local mine environmental impact statements (DIAND 1997), but few data are available on organochlorine contaminants or metals, particularly, in lake trout and char in the area. The area is also rich in uranium and there is a strong potential for the development of uranium mines. As a result, data are needed to define the baseline levels of radiation exposure to people in the area from natural radiation sources prior to the development of additional uranium mines. These issues were identified as priorities by elders at a workshop held in Baker Lake in December 1997 (Davey 1997). This project seeks to address these needs by conducting a study on organochlorines, metals and radionuclides in food items, and to conduct a field survey of background radiation in the community and its surrounding environment.

ACTIVITIES IN 1998/99 AND RESULTS

Administrative

A Baker Lake Environment Committee was formed in 1997, involving the community health representative, Hunters' and Trappers' Association, the GNWT Resource Officer and the Kivilliq Inuit Association (KIA), to examine issues involving contaminants in the Community and to coordinate projects related to environmental issues. The committee coordinated the contaminants workshop in December 1997 and also organised and oversaw the sampling of food and water for analysis. A resident of Baker Lake, Janet Nungnik, was hired by the Hamlet to act as the environmental coordinator for the project. The coordinator was key to the success of the collection of samples and in providing information on places where people in the community collect water and food. The concluding community workshop was held April 21-22, 1998 with a special session for students from the high school.

Environmental Sampling

A sampling program was conducted late in 1998 to measure background radiation levels in the community and to collect water and food samples for analysis. The program was a collaborative effort between the environmental coordinator, residents of the Hamlet, GNWT RWED (Resources, Wildlife and Economic Development), D. Kennedy of DIAND and C. Macdonald of Northern Environmental Consulting. Samples were collected and stored in Baker Lake and shipped to the laboratories for analysis.

(a) Background Gamma Radiation Survey

Background radiation was measured throughout the community by C. Macdonald using a Ludlum 19 gamma meter in two separate surveys. A partial survey was conducted in May 1998 to provide a rough idea of the range of exposures present, however, because snow, which was present on most roads, can cause shielding of background gamma, a more complete survey of the community was repeated in October 1998. Readings were taken at waist height approximately every 100 m along the roads and in areas with exposed outcrops of

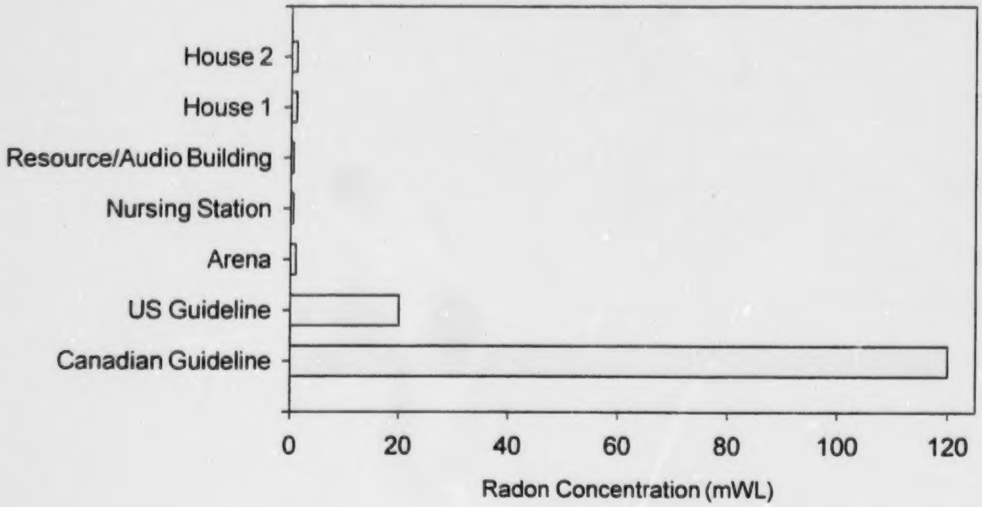

Figure 1. Comparison of measured radon levels with guidelines from the U.S. and Canada.

rock which could contain uraniferous rock. Background gamma radiation was also measured at several random sites that may have elevated radiation (e.g. exposed rock, gravel pits) and public buildings. The survey was conducted at 1 m height and at ground level using a hand-held Ludlum 19 gamma ratemeter which was calibrated for environmental temperatures of <-10°C. The meter was periodically checked with a ^{137}Cs check source.

The level of background gamma radiation was very consistent throughout the community, ranging from 8-15 $\mu R \cdot h^{-1}$ (dose in air). The highest levels of 20-22 $\mu R \cdot h^{-1}$ were observed on small rocks at the west end of the community, however, these levels were measured on contact with the rocks but dose rates at waist height were much lower. Exposed sand and gravel in pits at the east end of the community had the same dose rates as the rest of the community, suggesting that there are no sources of elevated natural radiation near the community. An average level of 10 $\mu R \cdot h^{-1}$ in air is a reasonable approximation of background dose. These levels are about the same or lower than in other areas of the NWT and in southern Canada. Despite the presence of uranium-rich rock south of Baker Lake, there was no indication of elevated background radiation which would indicate local sources of heightened exposure.

(b) Radon in Air

Radon in houses was measured using alpha track detectors marketed by the Canadian Institute of Radiation Protection (CAIRS) in Saskatoon. The detectors consist of a small aquarium pump which pulls air through a filter for a period of about one week. The tracks from the alpha particles in the detector are then counted in the CAIRS laboratory to give the concentration of radon in the air which passed through the filter.

Radon concentrations were measured in five buildings including two private houses (Figure 1). All radon concentrations were very low, with two of the buildings showing non-detectable levels after one week of sampling. These levels are much lower than the level of 20 mWL used as a guideline in the U.S. and the Canadian guideline of 120 mWL.

(c) Metals in Water

Water samples were collected from areas near the community which are routinely used for drinking water by the people in Baker Lake (e.g. Prince River mouth, Thelon River mouth). The sites were selected with members of the community and are given in Table 1 as GPS locations. At each site, two 1L samples were collected in linear polyethylene Nalgene containers and acidified, unfiltered, with concentrated HNO_3. Water samples were analysed by Envirotest, Edmonton by ICP/MS following standard Agriculture Canada, Environment Canada and USEPA protocols.

Table 1. The concentration of metallic elements in background water samples near Baker Lake as determined by ICP/MS. Concentrations are in $\mu g \cdot L^{-1}$. Elements which fall below a detection limit of 0.1 $\mu g \cdot L^{-1}$ in more than 50% of the sites: silver, beryllium, bismuth, cadmium, cobalt, cesium, molybdenum, antimony, thallium, and uranium. Other elements below their respective detection limits were mercury (DL = 0.01 $\mu g \cdot L^{-1}$), arsenic (0.2 $\mu g \cdot L^{-1}$), zinc (10 $\mu g \cdot L^{-1}$), selenium (10 $\mu g \cdot L^{-1}$), and lead (0.2 $\mu g \cdot L^{-1}$).

Site	GPS Location	Aluminum	Barium	Chromium	Copper	Iron	Lithium	Manganese	Nickel	Strontium	Titanium	Vanadium
Site 1	N 64° 22' 31.8"; W95° 52' 43.6"	23.8	11.1	0.525	0.95	0.05	0.75	3.9	0.55	19.45	0.75	0.125
Site 2	N 64° 19' 52.2"; W 95° 58' 00.8"	<25	14.2	0.5	0.9	0.04	0.8	2.4	0.5	22.3	0.5	<0.1
Site 3	N 64° 17' 57.2";" W 96° 04' 01.3"	159	19.4	0.4	13.1	0.19	0.9	9.3	0.7	18.9	4.3	0.4
Site 4	-	121	55.8	0.7	0.9	0.37	1.1	11.6	0.7	60.2	2.3	0.4
Site 5	N 64° 19' 08"; <25 W 96° 02' 48.2"	3.1	<2.0	16.2	0.1	0.4	3.8	1	8.8	0.5	0.2	
	Mean	**65.8**	**20.7**	**0.6**	**6.4**	**0.2**	**0.8**	**6.2**	**0.7**	**25.9**	**1.7**	**0.2**
	Standard deviation	**69.2**	**20.5**	**0.2**	**7.6**	**0.1**	**0.3**	**4**	**0.2**	**19.8**	**1.7**	**0.2**

Metal data for all sites are summarised in Table 1. The data are also presented in Figure 2 for five high priority metals, relative to the respective Canadian Water Quality Guidelines (CWQG). The concentration of all metals was well below the maximum acceptable concentration of the CWQG for the respective metals. Silver, beryllium, bismuth, cadmium, cesium, antimony, selenium, thallium, zinc and mercury were below detection limits at all five sites.

Based on the results of these samples, it is concluded that the levels of metals in drinking water from natural sources are low and it is unlikely that water is a major source of contaminant exposure to the residents of Baker Lake. Of primary interest, the levels of uranium remain below detection limits at all sites. These results are consistent with data from COGEMA Resources, Inc. which were submitted in the Environmental Impact Statement (EIS) in 1989 for the Kiggavik mine. The study reports levels of uranium below detection limits for several lakes and streams in the Baker Lake region. The maximum levels (11 $\mu g \cdot L^{-1}$) reported were in the Pointer Tributary which drained a mineralised area. The GNWT also tests municipal water supplied to residents in the community and there is no indication that metals are elevated in the municipal water supply. These results show that water remains a minor source of contaminants for the residents of Baker lake and there is presently no evidence of elevated metal concentrations in water.

(d) Contaminants in Food Samples

Samples of caribou, ptarmigan, lake trout and whitefish were collected by local hunters and fishers between October and December 1998 and shipped south for analysis of organochlorines, metals and radionuclides. A summary of the samples collected, the names of the contributing hunters and fishers and the dates of collection are listed in Table 2. Samples for radionuclide analysis were sent to Whiteshell Laboratories in Pinawa, MB. The samples were freeze-dried and analysed for radionuclides by gamma spectrometry using a p-type well-detector. The same samples were analysed for ^{210}Po by alpha spectrometry, after digestion and deposition onto silver discs, using ^{209}Po as a tracer. ^{210}Po at the date of collection was calculated by adding the unsupported fraction (decay-corrected to the plating date) and the supported fraction.

Nineteen food samples were shipped to CINE in October 1998 and January 1999 for organochlorine (OC) analysis. Considering that OC levels in land animals are usually very low, only 2 of the 4 caribou flesh samples were analysed. Levels of total PCBs (the sum of 51 congeners) and chlorinated pesticides (chlorobenzene (CBZ), hexachlorocyclohexane (HCH or lindane), dieldrin, heptachlor epoxide, chlordane, DDT, mirex) were measured.

The concentrations of all contaminants were low in the food samples (Tables 3, 4, 5). Raw data are presented in Macdonald (1999). Lead and arsenic were below the detection limit in ptarmigan and trout and were detected in a few samples of both caribou and whitefish. Cadmium was above the detection limit in only a few caribou samples and all the ptarmigan samples, however the mean value (0.022 $mg \cdot kg^{-1}$ wet weight (wt.)) for the ptarmigan was very low. The highest concentration of mercury (mean of 0.157 $mg \cdot kg^{-1}$ wet wt.) was found in lake trout. These levels are below Health Canada guidelines and are consistent with data from Environment Canada (Table 6) (D. Muir, pers. comm.) and show that the concentration of mercury is lower in char and whitefish than in lake trout in Baker Lake. All metals tested are relatively low in concentration. A more detailed exposure assessment, which considers the relative portion of each food item in the diet of the residents of Baker Lake, is required to support these tentative conclusions.

Radionuclides were also very low in concentration and there was no indication of contamination from local sources. Potassium-40 (^{40}K), a naturally-occurring radionuclide, was detectable in all samples at levels which are normal for all living material. The human-made radionuclide ^{137}Cs was detectable in all samples, but was at very low concentrations in ptarmigan, and both fish species. The elevated levels of ^{137}Cs in caribou are due to the higher levels in lichen which are caused by deposition from atmospheric nuclear tests during the 1960s. The levels in caribou are much lower than in earlier surveys of caribou, supporting the view that the concentration is consistently declining, probably with an environmental half-life of about 8 years. Similarly, ^{210}Po, a natural radionuclide which is produced by the decay of uranium, is low in fish and ptarmigan, and the higher levels in caribou reflect deposition from the atmosphere onto lichen.

Trace amounts of PCB were detected in 9 fish samples and 1 ptarmigan flesh sample. Only 2 samples had concentrations above 10 $ng \cdot g^{-1}$ wet wt. The highest concentration detected was 38 $ng \cdot g^{-1}$ wet wt. which is still at least 500 times (assuming 10% fat content) less than the guideline levels used by Health Canada for human consumption (2 ppm fat basis). No PCB was detected in the caribou samples.

No mirex or lindane was detected in any of the samples. Trace amounts (less than 10 $ng \cdot g^{-1}$) of CBZ, dieldrin, DDT and chlordane were detected in most of the samples. This trace amount of chemicals would be expected to be detected in any food items (i.e. any food bought from the market). The highest DDT concentration (25 $ng \cdot g^{-1}$) was found in a trout sample which is at least 2000 times (assuming 10% fat content) less than the

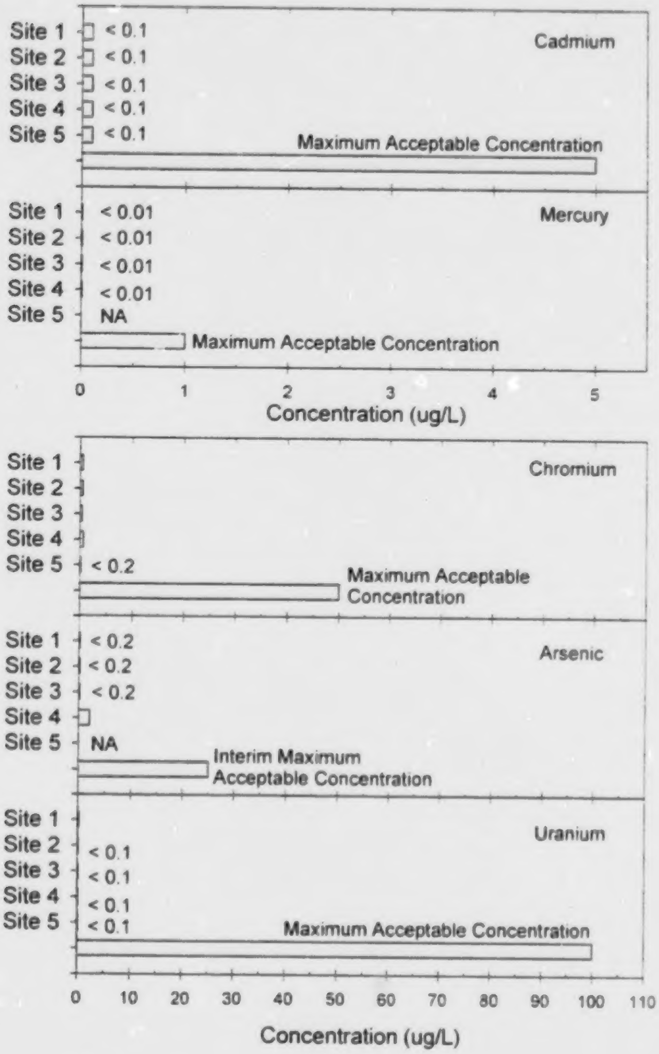

Figure 2. The concentration of five priority metals relative to Canadian Drinking Water Guidelines in the five sampling sites near Baker Lake.

Table 2. Summary data for samples collected at Baker Lake, Nunavut, which were analysed for organochlorines, metals and radionuclides.

Sample Species	Hunter/ Fisher	Sample Type	Location	Date of Collection	Sample Number	Comment
Caribou	Jeremy Singaqti	muscle	42 km N.E. Baker Lake	October 5, 1998	BL98CB1	male
	Luke Tunguaq	muscle	Pitts lake	October 4, 1998	BL98CB2	
	William Aupalaktuk	muscle	25 km N.E. Baker Lake	October 15, 1998	BL98CB3	
	Jeremy Singaqti	muscle	33 km N.E. Baker Lake	October 6, 1998	BL98CB4	
	Elijah Amarook	muscle	Prince River area	October 20, 1998	BL98CB5	
Ptarmigan	Martha Nukik	whole body	Baker Lake area	October 28, 1998	BL98PT1	meat for metal analysis
	Martha Nukik	whole body	Baker Lake area	October 28, 1998	BL99PT1	meat for radionuclide analysis
	Martha Nukik	whole body	Baker Lake area	October 26, 1998	BL99PT2	meat for metal analysis
	Martha Nukik	whole body	Baker Lake area	October 28, 1998	BL99PT3	meat for metal analysis
	Martha Nukik	whole body	Baker Lake area	October 28, 1998	BL99PT4	meat for radionuclide analysis
Lake Trout	William Noah	whole body	Prince R. mouth, Baker Lake	October 1, 1998	BL98LT1	FL=48.6 cm, TL=53.2 cm; 1.7 kg; male
	William Noah	whole body	Prince R. mouth, Baker Lake	October 1, 1998	BL98LT2	FL=42.8 cm, TL=46.2 cm; 1 kg; male
	William Noah	whole body	Prince R. mouth, Baker Lake	October 2, 1998	BL98LT3	FL=56.9 cm, TL=62.4 cm; 2.2 kg; female
	Nick Nungnik	whole body	Baker Lake	October 29, 1998	BL99CH1	
	Nick Nungnik	whole body	Baker Lake	October 29, 1998	BL99CH2	
Whitefish	William Noah	whole body	Prince River mouth	October 1, 1998	BL98WF1	FL=31.7 cm, TL=34.5 cm; 0.23 kg
	William Noah	whole body	Prince River mouth	October 1, 1998	BL98WF2	FL=33.9 cm, TL=37.0 cm; 0.45 kg
	Nick Nungnik	whole body	Baker Lake	October 29, 1998	BL99WF1	
	Nick Nungnik	whole body	Baker Lake	October 29, 1998	BL99WF2	
	Nick Nungnik	whole body	Baker Lake	October 29, 1998	BL99WF3	
	Nick Nungnik	whole body	Baker Lake	October 29, 1998	BL99WF4	

Table 3. Mean (standard deviation) concentration of metals (mg·kg^{-1} wet wt.) in four major food species.

Sample	Arsenic	Lead	Cadmium	Mercury
Caribou	0.002 (0.001)	<0.019	<0.002	0.017 (0.006)
Ptarmigan	<0.0025	<0.019	0.022 (0.011)	0.006 (0.004)
Lake trout	<0.0025	<0.019	<0.002	0.157 (0.035)
Whitefish	<0.0025	<0.019	<0.002	0.072 (0.007)

Table 4. Summary of radionuclide concentrations in caribou, ptarmigan and fish collected in Baker Lake in 1998/99. Concentrations are in Bq·kg^{-1} wet wt. Americium-241 (DL = 0.25 Bq·kg^{-1} wet wt.) and uranium-235 (DL = 1.0 Bq·kg^{-1} wet wt.) were below detection limits in all samples.

Species	Dry Weight (%)	Ash Weight (%)	^{40}K	^{137}Cs	^{210}Pb	^{232}Th	^{226}Ra	^{210}Po
Caribou	26.7 (1.2)	2.2 (0.5)	192 (13)	131 (42)	< 3.2	< 0.74	< 0.5	11.5 (4.5)
Ptarmigan	28.0 (0.7)	1.82 (0.38)	156 (56)	2.60 (0.93)	< 2.8	< 0.69	< 1.0	0.41 (0.07)
Lake trout	23.1 (2.0)	1.3 (0.2)	210 (8)	3.6 (0.5)	< 2.3	< 0.57	< 0.4	0.10 (0.01)
Whitefish	22.1 (1.9)	1.3 (0.1)	200 (43)	2.6 (1.0)	< 3.0	< 0.77	< 0.63	0.54 (0.36)

Table 5. Summary of organochlorine concentrations in the four food species tested. Concentrations are in ng·g^{-1} wet wt.

Species	Chlorobenzene	Lindane	Dieldrin	DDT	Chlordane	Heptachlor epoxide	Mirex	Total PCB
Caribou	0.74 (0.97)	< 0.1	< 0.1	2.84 (1.29)	0.68 (0.65)	< 0.1	< 0.1	< 0.1
Ptarmigan	< 0.1	< 0.1	9.10 (15.6)	2.45 (0.46)	0.61 (0.46)	< 0.1	< 0.1	< 0.1
Lake Trout	4.76 (7.78)	< 0.1	< 0.1	2.53 (2.81)	3.91 (2.63)	< 0.1	< 0.1	6.35 (4.74)
Whitefish	1.80 (1.72)	< 0.1	< 0.1	6.99 (9.63)	4.45 (3.07)	< 0.1	< 0.1	9.51 (14.3)

Table 6. Mercury and organochlorine data for arctic char, lake trout and lake whitefish collected in Baker Lake, Nunavut. Data are from D. Muir, Environment Canada, Burlington (*pers. comm.*). Unless otherwise noted, all units are µg·kg^{-1} wet wt.

															PCBs					
Genus/ Species	**% Lipid**	**Weight (g)**	**Hg (µg·g^{-1} ww.)**	**HCBz**	**ΣCBZ**	**α-HCH**	**ΣHCH**	**Oxy-chlor**	**ΣChlor**	**Dield**	***pp*-DDE**	**ΣDDT**	**Mirex**	**ΣTOX**	**CB52**	**CB153**	**CB138**	**CB180**	**CB170**	**Total**
Arctic Char (*Salvelinus alpinus*) (n=6)																				
Mean	8.1	2353	0.05	1.94	3.16	1.31	2.37	0.54	4.37	0.13	1.13	5.43	0.16	2.87	0.38	1.72	0.57	0.23	0.09	12.19
S.D.	4.2	639	0.01	1.15	2.14	0.91	1.65	0.43	3.05	0.09	1.04	3.09	0.10	1.82	0.17	1.18	0.60	0.17	0.07	6.00
Lake Trout (*Salvelinus namaycush*) (n = 4)																				
Mean	13.5	2538	0.25	2.27	2.64	1.11	1.21	1.38	9.42	1.15	4.41	11.79	0.33	12.61	0.55	6.22	5.09	1.89	0.54	41.77
S.D.	5.9	878	0.06	1.05	1.11	0.34	0.38	0.69	2.94	0.46	2.12	3.72	0.11	5.93	0.12	2.20	2.05	0.56	0.15	14.47
Lake Whitefish (*Coregonus clupeaformis*) (n=3)																				
Mean	5.8	2783	0.08	1.95	2.26	0.36	0.73	0.29	3.91	0.13	0.90	3.35	0.08	ND	0.49	1.15	0.86	0.31	0.17	12.37
S.D.	5.0	1241	0.01	0.83	0.88	0.18	0.16	0.14	0.54	0.02	0.35	0.59	0.02		0.18	0.11	0.20	0.05	0.02	2.12

guideline levels used by Health Canada for human consumption (5 ppm fat basis). These levels are consistent with a survey of organochlorine levels in lake trout, char and whitefish by D. Muir (Table 6).

There is minimal health risk from organochlorines associated with consumption of these samples. A more comprehensive risk assessment will be performed once the dietary information that is being collected by CINE is available.

(e) Quality Assurance and Quality Control

All laboratories participating in this study conducted extensive QA/QC as part of the analysis for this project, as well as maintaining full QA/QC programs to maintain accreditation and to fulfill their role within government (i.e. for site licensing for Whiteshell Laboratories). Routine QA with sample analysis includes spiked and reference samples as well as estimates of precision and accuracy.

DISCUSSION/CONCLUSIONS

The levels of metals and organochlorines reported in this study for food and water samples are relatively low compared to other areas in Nunavut and the Northwest Territories. Major organochlorines are close to detection limits in caribou and ptarmigan, while slightly higher levels are observed in fish. Although a detailed exposure assessment is presently being conducted by CINE as part of a larger diet study in several communities in Nunavut, it is likely that the exposure of Baker Lake residents to organochlorines will be low compared to other Nunavut communities because of the reliance of the community on terrestrial foods which have much lower contaminant levels than marine animals.

Radionuclides are also low in food and water in Baker Lake, and environmental radiation in the form of radon gas and background gamma radiation is also low. This is a major finding of this study because of the concern of Baker Lake residents for possible radioactive sources in the area and the need for establishing background radiation exposure prior to the development of major uranium deposits in the area. There was no evidence that these deposits significantly increased the levels of uranium, or any of the decay chain products, in food or water during the time of this study. The assessment should be repeated in the event that large scale development of local uranium deposits takes place.

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METALS AND ORGANIC CONTAMINANTS IN BEAVER AND MUSKRAT IN THE SLAVE RIVER DELTA AREA, NWT

Project Leader: David Kennedy, Contaminants Division, Department of Indian Affairs and Northern Development (DIAND)

Project Team: Maurice Boucher, Fort Resolution Environmental Working Committee (FREWC); Brett Elkin, GNWT Resources, Wildlife and Economic Development (RWED); Aboriginal Wildlife Harvesters Committee (AWHC) of Fort Resolution; Deninu Ku'e First Nation; Lands and Environment Department, Dene Nation

OBJECTIVES

1. To measure levels of metals, organochlorines and dioxins and furans in beaver and muskrat of the Slave River Delta and nearby basins to determine if they are safe for consumption; and

2. To involve and train community members in environmental sampling.

DESCRIPTION

This project was undertaken to address the concerns of the community of Fort Resolution, NT about contaminant levels in beaver and muskrat, which are traditionally important food items to this community at the edge of the Slave River Delta. The Fort Resolution Environmental Working Committee (FREWC) ap-proached the Northern Contaminants Program (NCP) because of recent reports that the delta is a sink for contaminants.

The Slave River drains approximately 600,000 square kilometres, including parts of northern British Columbia, Alberta and Saskatchewan. Several studies have shown that the Slave River is a means of contaminant transport into the Northwest Territories and that the delta is an area of deposition of contaminant-laden sediments (Milburn and Prowse 1998, Sanderson *et al.* 1997, Evans *et al.* 1997). Figure 1 shows the sample rivers and the entire Slave River watershed.

Fort Resolution residents consume muskrat and beaver year-round: in winter, 29% consume muskrat and 16% consume beaver; in summer, 46% consume muskrat and 11% consume beaver (Receveur *et al.* 1996). No data set exists for contaminant levels of beaver and muskrat in the NWT. The Yukon has a complete set of contaminants data for all mammals used for food. The establishment of contaminant levels in beaver and muskrat will assist the NWT in completing its data set and will be useful to local residents in making informed food choices.

The project was designed by the project team as a whole. It was decided that samples would be collected in the Slave River Delta and in other areas that are regularly trapped for food. These other sites are control sites for determining if contaminant levels in beaver and muskrat in the Slave River Delta are higher than in other smaller localized habitats. The budget for this project allowed for analyses of muscle and liver of twelve samples of each species. Through sample and analytical design, the project team optimized the value and amount of information that could be derived. It is recognized that the project, while not statistically robust, would provide important information on contaminant levels in beaver and muskrat in an area which potentially acts as a sink for river-borne pollutants, and may identify contaminant issues that require further investigation.

ACTIVITIES IN 1998/99

Under the direction of the Fort Resolution Environmental Working Committee (FREWC), local trappers were commissioned to collect samples in May 1998. The FREWC representative, Maurice Boucher, received instruction in sample collection procedures from Dr. Brett Elkin, an experienced NCP researcher, based on sample collection protocols developed by the Centre for Indigenous Peoples' Nutrition and Environment (CINE). Mr. Boucher instructed the hunters and trappers in sample handling and helped with collection and storage. Samples were collected from the Slave River delta, Jean River, Talston River and Little Buffalo River. The sample collection took place in mid- to late May. The animals were taken by gun and, in the field, trappers weighed, measured, determined sex, and took tissue samples of each animal. For each animal, a sample of muscle and liver were taken and placed in separate clean, labeled Whirl-pak® bags. The skulls (for tooth extraction and cementum ageing) were tagged with animal identification

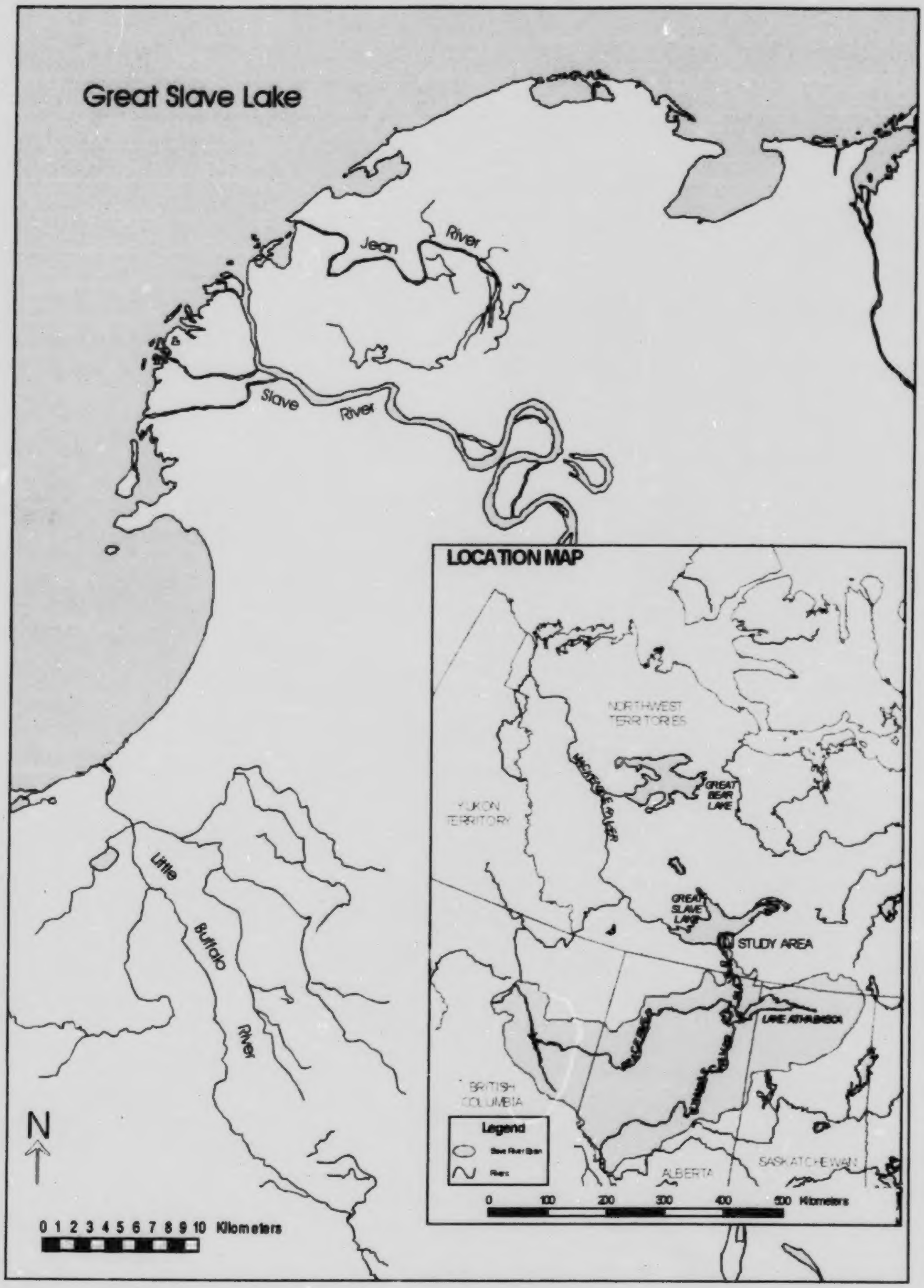
Great Slave Lake
Jean River
Slave River
Little Buffalo River
N
0 1 2 3 4 5 6 7 8 9 10 Kilometers
LOCATION MAP
NORTHWEST TERRITORIES
YUKON TERRITORY
GREAT BEAR LAKE
GREAT SLAVE LAKE
STUDY AREA
LAKE ATHABASCA
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
Legend
Slave River Basin
Rivers
0 100 200 300 400 500 Kilometers

Figure 1. Location map and sample rivers.

Table 1. Mean concentrations of metals in beaver and muskrat in the Slave, Jean and Little Buffalo rivers. ($\mu g \cdot g^{-1}$ or ppm dry weight unless otherwise stated)

Tissue	As [5]	Cd [0.1]	Cr [2]	Co [0.1]	Cu [0.1]	Fe (% weight) [.002]	Pb [0.2]	Mn [0.1]	Hg (wet wt.) [0.01]	Ni [0.1]	Zn [10]
Beaver Liver (N=12)											
Mean	nd	6.60	nd	0.12	13.12	0.0588	0.15	13.10	nd	0.1*	127.5
Standard Deviation**		5.79			1.54	0.0252		1.54			20.5
Percent detection		100		42	100	100	33	100		8	100
Beaver Muscle (N=12)											
Mean	nd	nd	nd	nd	4.90	0.0237	3.6*	0.88	nd	nd	134.8
Standard Deviation					1.67	0.0085		0.74			63.1
Percent detection					100	100	8	100			100
Muskrat Liver (N=10)											
Mean	nd	0.65	nd	0.15	10.15	0.1450	nd	7.46	.01*	0.2*	77.8
Standard Deviation		0.51		0.06	3.2	0.0380		1.79			10.4
Percent detection		80		80	100	100		100	10	10	100
Muskrat Muscle (N=9)											
Mean	nd	nd	nd	nd	3.59	0.0270	0.17	0.77	nd	0.1*	68.0
Standard Deviation					1.16	0.0069		0.036			21.6
Percent detection					100	100	33	100		11	100

[ ] - detection limit (DL), $\mu g \cdot g^{-1}$ unless otherwise stated

nd - not detected

When detection percentage less than 100%, 1/2 DL used for nd in calculation of the mean, unless:

* - one detection only, value given

** Standard deviation calculated only if detection percentage greater than 50%

Table 2. Data Summary of organochlorines in Beaver and Muskrat muscle and liver in the Slave, Jean and Little Buffalo rivers. ($ng \cdot g^{-1}$ or ppb wet weight).

Organochlorine*	**Jean River**				**Slave River Delta**				**Little Buffalo River**			
	Beaver		**Muskrat**		**Beaver**		**Muskrat**		**Beaver**		**Muskrat**	
[DL=0.1 $ng \cdot g^{-1}$ for all]	**muscle**	**liver****	**muscle**	**liver****	**muscle**	**liver****	**muscle**	**liver****	**muscle**	**liver****	**muscle**	**liver****
PCB (total)	6.46	0.59	1.66	0.15	nd	0.11	nd	1.50	1.01	0.22	9.86	nd
Chlorobenzene	0.34	0.17	0.39	0.17	nd	0.24	nd	0.11	nd	0.25	nd	0.06
Dieldrin	nd	1.02	nd	1.03	nd	nd	nd	2.06	nd	nd	nd	nd
DDT	nd	1.04	nd	6.10	29.62	3.48	23.85	4.21	12.54	2.62	22.43	4.49
Chlordane	nd	1.03	nd	1.66	4.94	nd	nd	0.63	2.51	0.58	3.74	0.40

* Also measured but not detected: HCH (Lindane), mirex and heptachlor epoxide

** Liver results expressed as mean of multiple analyses if more than one single/pool carried out; 1/2 DL used for a non-detection in calculation of the mean of multiple analyses

nd = not detected

numbers, and the stomach contents were placed in labeled bags. The samples were frozen and sent to Yellowknife for processing before being sent to the labs. Due to sample set gaps, and to comply with the budget, the Talston River samples were not sent for chemical analyses and remain in archive.

Each animal (muscle and liver) was analysed for arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) by ICP-MS, and for total mercury (Hg) using cold vapour atomic absorption at Taiga Environmental Laboratory in Yellowknife. Muscle and liver samples were analysed for organochlorines by GC-MS at the CINE laboratory at McGill University in Montreal. The dioxins (PCDDs) and furans (PCDFs) analyses, also done with GC-MS, were performed on liver homogenates of each species by Axys Analytical Services of Sidney, B.C.

An M1 molar was extracted from each beaver and muskrat and sent to Matson's Laboratory in Montana for cementum analysis to determine the age of the animals. This process involves taking a vertical section of the M1 molar and analysing tooth growth patterns. The stomach contents were studied by a biological technician in Yellowknife to determine the primary food sources of the animals.

All laboratory tests were completed in late March, 1999. A public results reporting meeting was held in Fort Resolution on May 26, 1999.

All contaminants data have been sent, via the NWT Environmental Contaminants Committee, for a health risk assessment by GNWT Health.

RESULTS AND DISCUSSION

According to the tooth cementum analysis, the two species were quite different in age pattern. All ten muskrat were one to two years old and there was no significant difference between ages in muskrats from the different river systems. The beaver ages were more variable, with ages ranging from one to six years; three of the eleven animals were three years old or more. In general, beavers from the Jean River were the oldest (average 3.67 years) and Slave Delta beaver were the youngest (average 1.25 years).

The stomach content analyses proved somewhat problematic, as the contents for both beaver and muskrat were very well digested. A microhistological examination was required to identify plant species, and unfortunately, only an incomplete reference set for northern aquatic and terrestrial plants was available to the technician. The stomach contents underwent a screening exercise to determine, at a minimum, the major food sources for the animals. The most common food plants in both beaver and muskrat were horsetails (*Equisetum* spp.) and scouring rush (*Equisetum hyemale*). All muskrat stomachs contained horsetail; the stomachs of eight of the beavers had over 50% scouring rush content. The beaver also contained sedges (*Carex* spp.), cattail (*Typha latfolia*), aspen (*Populus tremuloides*), willow (*Salix* spp.), white birch (*Betula papyrifera*), balsam poplar (*Populus balsamifera*) and possibly alder (*Alnus crispa*), as well as some unidentified aquatic plants. Muskrat contained mostly horsetail, some sedges and other unidentified aquatic plants. No evidence was found of mollusks, aquatic invertebrates, fish or amphibians.

Contaminants Analyses

Metals

The metals levels in all tissues were generally low and are probably indicative of natural background levels (see Table 1). There was no statistically significant difference between the means of samples (for Cd, Fe, Cu, and Zn) from the three river systems, except Cu in livers. Copper concentrations in liver were significantly higher in beaver from the Slave River than from other rivers, and were significantly lower in muskrat from the Little Buffalo River than from other rivers. As expected, cadmium levels in beaver liver have a strong linear positive correlation with age. No other age-dependent relationships were found.

There are few existing data for the NWT with which to compare our results. An analysis of one beaver, from Lake B near the Rayrock mine west of Great Slave Lake, had 0.25 $\mu g \cdot g^{-1}$ Cd in the muscle (Hatfield Consultants 1985). Cadmium levels in the Yukon beaver livers were around 13 $\mu g \cdot g^{-1}$ dry weight (Gamberg, unpublished data, 1995); for this study, the mean level was 6.6 $\mu g \cdot g^{-1}$ dry weight. The mean level of Cd in beaver liver taken from central Ontario was 0.19 $\mu g \cdot g^{-1}$, while Cd in the muscle was not detected (Wren 1984). The Yukon data compare very closely for Cu results in the livers for both muskrat (11.25 $\mu g \cdot g^{-1}$) and beaver (13.36 $\mu g \cdot g^{-1}$) (Gamberg, unpublished data, 1995). Some values for Cd in muskrat liver inlcude: Pennsylvania - 0.053 $ug \cdot g^{-1}$ (Erickson and Lindzey 1983); and Flin Flon, MB - 0.306 $\mu g \cdot g^{-1}$ (Radvanyi and Shaw 1981).

The only consumption advisory for beaver is in the Yukon. The Yukon Health and Social Services recommended that Yukoners not consume more than 46 beaver livers per year, and not more than 15 kidneys per year, with no advisory on the meat (muscle).

Organochlorines

The organochlorine analyses included: PCBs (the sum of 51 congeners), chlorobenzene (CBZ), hexachlorocyclohexane (HCH or Lindane), dieldrin, heptachlor epoxide, chlordane, DDT and mirex. Each sample was scanned for toxaphene at the full scan mode of the GC-MS. No significant peak was observed, therefore, the concentration of toxaphene in every sample is below 20 ppb. It was decided that the quantitative measurement of toxaphene below 20 ppb using MS/MS was not justified. Table 2 shows the summary of results of the organochlorine analyses.

The muscle tissues were pooled by species and site (six pools); the liver samples consisted of four pooled samples and twelve individual samples. The results showed trace amounts of organochlorine contaminants, with many results below the detection limit of 0.1 ng·g^{-1} (ppb) wet weight. PCBs were detected in 13 of the 21 samples analysed. The concentrations were all well below 10 ng·g^{-1} wet weight, and at least 200 times below Health Canada guidelines for human consumption. DDT levels are at least 15 times below the Health Canada guideline for human consumption. All other pesticide concentrations, if detected, were below 10 ng·g^{-1}, levels representative of that found in any food that would be bought in a market. There were no obvious differences between beavers and muskrats or between sample sites (or river systems). In his report, Dr. Laurie Chan of CINE states that "There is minimal health risk [from organochlorines] associated with consumption of these beavers and muskrat."

A study of organochlorines in food items in the Fort Good Hope - Colville Lake area (Muir *et al.* 1989) showed similar levels of organochlorines in beaver and muskrat flesh (generally less than 10 ng·g^{-1} wet weight). The Yukon beaver and muskrat data (Gamberg, unpublished data, 1995) also show few detections at very low levels.

Homogenates of beaver and muskrat livers were analysed for 17 dioxin and furan compounds which contribute most to the toxicity of complex mixtures found in the environment. The relative toxicity of each compound is expressed in relation to the most toxic compound, T4CDD or 2,3,7,8-tetrachlorodibenzodioxin, which is assigned the International Toxic Equivalency Factor (ITEF) of 1.0.

Almost all dioxins and furans tested for were not detectable at the 0.1 to 0.2 pg·g^{-1} (ppt) detection limits. T4CDF, the most toxic furan at 0.1 ITEF (one tenth the toxicity of T4CDD), was detected at the detection limit of 0.1 pg·g^{-1} in muskrat liver. H7CDF and H7CDD (each 0.01 ITEF) were detected in muskrat and beaver, ranging from 0.5 to 2.1 pg·g^{-1}. Both species also contained O8CDD (0.001 ITEF) and O8CDF (0.001 ITEF), which were in the 0.3 to 5.1 pg·g^{-1} range for all detections. Again, the data are comparable to the Yukon data.

PROJECT COMPLETION

A summary of the results has been sent to Deninue Kue First Nation for translation and posting. A leaflet/poster of the results will also be developed, in cooperation with the project team, for public information. The results will be further interpreted after the health risk assessment and prepared for publication in a refereed journal.

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MERCURY IN FISH FROM SURVEYS IN LAKES IN THE WESTERN NORTHWEST TERRITORIES

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OBJECTIVES

1. To determine the occurrence and geographic distribution of mercury, selenium and arsenic in fish from those inland lakes in the NWT being assessed for their ability to produce sustained yields of fish for subsistence consumption by Northern people.
2. To evaluate the levels of mercury found in the fish in terms of the age/size relationships of the fish and also in terms of the geological setting of each lake and its drainage, with a view to developing a management strategy of recommended consumption levels based on species and size of fish on a lake-by-lake basis.

DESCRIPTION

Historical DFO Inspection Service data indicate that muscle mercury levels in some of the larger fish from a number of lakes in the Northwest Territories exceed levels recommended for human consumption. Several lines of evidence suggest that inputs of mercury to northern Canada have increased over pre-industrial levels. Mercury in arctic seals and whales has increased since the 1970s (Wagemann *et al.* 1996). Sediment core data from a number of lakes in the NWT have suggested that recent mercury inputs are above pre-industrial levels (Lockhart *et al.* 1998). Given these considerations, it is important to assess the levels of mercury in stocks of fish being used now or being assessed for potential harvest in the near future. The lake survey process provides samples for analysis without significant incremental costs to the sample collection process. By the end of the project, we hope to develop models to help predict levels of mercury based on fish species and size, food chain structure, lake and drainage limnology, atmospheric loadings and geological settings. The Northern Contaminants Program (NCP) workshop on mercury identified the discrimination between natural and anthropogenic sources of mercury as one of the priority issues.

It is anticipated that future human consumption risk assessments will find it useful to know not only the concentrations of mercury but also the concentrations of selenium in the same organs. For that reason, we analysed for both selenium and mercury.

There is some evidence of high levels of arsenic in inconnu and some burbot from the lower Mackenzie River (Lockhart *et al.* 1999). However, we lack sufficiently widespread data on arsenic levels in fish throughout the western NWT to make a well informed assessment and we therefore proposed to analyse arsenic in a subset of the fish.

Several factors appear to influence the level of mercury in fish tissues including fish age (or length), the structure of the supporting food chain, water chemistry, lake temperature, microbiological processes in the sediments, fish biochemistry, the supply of mercury to the lake and the nature of the basin and catchment (e.g. rocks, uplands, wetlands, etc.). The supply of mercury is a mixture of natural geological contributions, with any human-related contributions appearing as additions to the natural supply. Consequently, an important step in under-standing the levels in fish from the western NWT is to examine the geological settings of the lakes and their drainage basins.

ACTIVITIES IN 1998/99

Fish samples were obtained from several lakes (Sibbeston, Loon, Tsetso, Manuel); most have been analysed for mercury and some have been analysed for selenium and arsenic. Analyses were delayed for several months because of an analytical problem at the Freshwater Institute. Throughout most of the winter of 1998/99, quality control on mercury analyses were unsatisfactory. The cause of the problem is speculative but it affected several laboratories operating independently and was coincident with building roof repairs and interior painting. In our laboratories, the quality of selenium and arsenic analyses were also affected. The quality problems appear to have abated for mercury but remain troublesome for both selenium and arsenic.

Topographic maps were studied at the Geological Survey of Canada, in Ottawa, in order to construct maps describing some of the morphological and geological features of the sites.

RESULTS

Results for mercury concentrations in fish are presented as tables of descriptive statistics calculated in two ways. Conventional arithmetic means and standard deviations were calculated using the 'PROC MEANS' procedure of SAS and correlation coefficients were obtained from the 'PROC CORR' procedure. Comparisons of means were made using the 'LSMEANS' option of the 'PROC GLM' procedure. Mercury concentrations are also shown graphically as scatter plots with muscle mercury levels plotted against fish length. Regression equations were calculated by the 'robust regression' technique of the NCSS-2000 program. The robust regression technique tests data for statistical outliers and removes them from the calculation in order to prevent excess influence of unusual values.

Sibbeston Lake mercury (61°45' N, 122°45' W)

Mercury in muscle samples of fish from Sibbeston Lake are shown in Table 1 and plotted as a scatter diagram in Figure 1A. We obtained quite a large number of lake whitefish (143) from this lake and the levels of mercury in them were low (arithmetic mean = 0.071 $\mu g \cdot g^{-1}$. However, the large number of samples and the good range of sizes represented make this a useful set of data for future studies of temporal change. The R-squared value of 0.59 was highly significant, indicating that longer fish have higher mercury levels. The relationship between length and mercury is probably the best way to compare these data with future data in efforts to detect any temporal changes The numbers of fish of the other three species were too small to support firm conclusions. Mercury in the five walleye ranged from 0.2 to 0.45 $\mu g \cdot g^{-1}$, an indication that additional samples from that species should be analysed. The seven white suckers had low levels of mercury but they fell in a pattern of increasing with fish length so that the R-squared value was high in spite of the small sample size.

Tsetso Lake mercury (61°51' N, 123°01' W)

Mercury concentrations in lake whitefish from Tsetso Lake (Table 2, Figure 1B) were about the same as those in nearby Sibbeston Lake (Table 1). However, the ranges in sizes of the fish from Tsetso were more restricted and so the R-squared values for regressions of mercury on length were reduced (Table 2). We obtained a good sample of walleye from Tsetso Lake (N=99) and the arithmetic mean value was 0.49 $\mu g \cdot g^{-1}$, just under the criterion for commercial fish. In fact, almost half the walleye (44 of 99) had mercury at 0.5 $\mu g \cdot g^{-1}$ or higher (Figure 1B). All but three of the walleye exceeded the lower consumption criterion of 0.2 $\mu g \cdot g^{-1}$. Only three northern pike were obtained with an arithmetic mean mercury concentration of 0.39 $\mu g \cdot g^{-1}$; more northern pike from this lake should be analysed.

Manuel Lake mercury (66°59' N, 128°55' W)

We obtained samples of fish from Manuel Lake on several occasions from 1993 to 1998. The composite data are summarized in Table 3 and shown graphically in Figure 1C. We obtained more burbot (30) from this lake than from most others and mercury levels in them fell in the range of 0.14-0.45 $\mu g \cdot g^{-1}$; with an arithmetic mean of 0.26 $\mu g \cdot g^{-1}$ (Table 3). Lake whitefish had lower levels with the maximum mercury content being 0.3 $\mu g \cdot g^{-1}$ and the arithmetic mean 0.12 $\mu g \cdot g^{-1}$. Lake trout were similar to burbot; they ranged from 0.19-0.46 $\mu g \cdot g^{-1}$ with a mean of 0.3. Northern pike had the highest mercury levels among the species obtained with a range of 0.14-1.78 $\mu g \cdot g^{-1}$. The arithmetic mean of 0.45 $\mu g \cdot g^{-1}$ fell just under the line at 0.5 $\mu g \cdot g^{-1}$ shown in Figure 3. All the species showed the usual tendency of increasing mercury levels with increasing fish size. Health Canada evaluated some of the earlier data from this lake and advised that consumption of northern pike be restricted to 430 g per week and half that amount for children or women of child-bearing age.

Loon Lake mercury (66°37' N, 128°43' W)

We obtained only a few samples from Loon Lake (6 lake trout, 14 northern pike; Table 4 and Figure 1D). The lake trout mercury levels were tightly clustered in the 0.33 to 0.4 range with a mean of 0.37 $\mu g \cdot g^{-1}$. There was a weak tendency for increased mercury in larger fish, but the slope of the regression was very shallow. The northern pike had a broader range of mercury concentrations (0.27–0.72 $\mu g \cdot g^{-1}$) and a higher arithmetic mean of 0.51 $\mu g \cdot g^{-1}$. Larger fish generally had higher mercury levels; the R-squared value of 0.547 for the slope was lower than for lake trout but the regression slope had a higher level of statistical significance.

Watershed maps

Mapping studies have begun to describe the watersheds of some of the lakes. For example, Figure 2 shows the approximate watersheds and wetlands in the system that contains Cli, Little Doctor, Tsetso and Sibbeston lakes. The map shows that two of these, Cli and Little Doctor, are located on geological faults but the other two, Tsetso and Sibbeston, are not. These data offer an opportunity to compare mercury levels in fish from the four lakes to see whether the presence of the faults may be associated with differences in mercury levels in fish

Table 1. Summary statistics describing mercury levels in fish from Sibbeston Lake.

Arithmetic mean calculations from SAS

Sibbeston Lake		**N**	**Arith. Mean**	**S.D.**	**Min**	**Max**
Lake whitefish	Length	143	421.6	39.7	315	570
	Hg	143	0.071	0.024	0.030	0.200
Walleye	Length	5	468.0	53.7	418	554
	Hg	5	0.328	0.120	0.200	0.450
Northern pike	Length	2	670.5			
	Hg	2	0.165			
White sucker	Length	7	506.4	41.4	420	545
	Hg	7	0.136	0.058	0.050	0.200

Robust regression calculations from NCSS

Sibbeston Lake		**N**	**Mean ± S.D.**	**Intercept**	**Slope**	**R-squared**
Lake whitefish	Hg	141	0.067 ± 0.015	0.083	0.00036	0.599*
Walleye	Hg	5	0.330 ± 0.110	0.363	– 0.00007	0.001
Northern pike	Hg	2	0.169 ± 0.046			
White sucker	Hg	7	0.141 ± 0.051	– 0.446	0.00117	0.838*

*Significant at 5 % probability level

Table 2. Summary statistics describing mercury levels in fish from Tsetso Lake.

Arithmetic mean calculations from SAS

Tsetso Lake		**N**	**Arith. Mean**	**S.D.**	**Min**	**Max**
Lake whitefish	Length	102	421.4	22.5	367	470
	Hg	102	0.075	0.030	0.030	0.200
Walleye	Length	99	493.1	31.3	382	561
	Hg	99	0.486	0.126	0.120	0.750
Northern pike	Length	3	763.3	122.3	664	900
	Hg	3	0.393	0.153	0.260	0.560

Robust regression calculations from NCSS

Tsetso Lake		**N**	**Mean ± S.D.**	**Intercept**	**Slope**	**R-squared**
Lake whitefish	Hg	101	0.069 ± 0.018	– 0.137	0.000489	0.286*
Walleye	Hg	99	0.475 ± 0.087	– 0.208	0.00138	0.155*
Northern pike	Hg	3	0.466 ± 0.112	0.600	0.00161	0.012

*Significant at 5 % probability level

Table 3. Summary statistics describing mercury levels in fish from Manuel Lake.

Arithmetic mean calculations from SAS

Manuel Lake		**N**	**Arith. Mean**	**S.D.**	**Min**	**Max**
Lake whitefish	Length	41	509.9	36.5	432	638
	Hg	41	0.119	0.061	0.040	0.30
Burbot	Length	30	632.1	43.5	563	730
	Hg	30	0.257	0.081	0.140	0.450
Lake trout	Length	19	484.7	29.8	433	545
	Hg	19	0.299	0.064	0.210	0.460
Northern pike	Length	38	643.8	51.7	560	830
	Hg	38	0.452	0.244	0.140	1.760

Robust regression calculations from NCSS

Manuel Lake		**N**	**Mean S.D.**	**Intercept**	**Slope**	**R-squared**
Lake whitefish	Hg	41	0.117 ± 0.048	– 0.464	0.00114	0.574*
Burbot	Hg	30	0.231 ± 0.052	– 0.382	0.00097	0.469*
Lake trout	Hg	19	0.289 ± 0.039	– 0.068	0.00074	0.220*
Northern pike	Hg	37	0.440 ± 0.082	– 0.569	0.00158	0.482*

*Significant at 5 % probability level

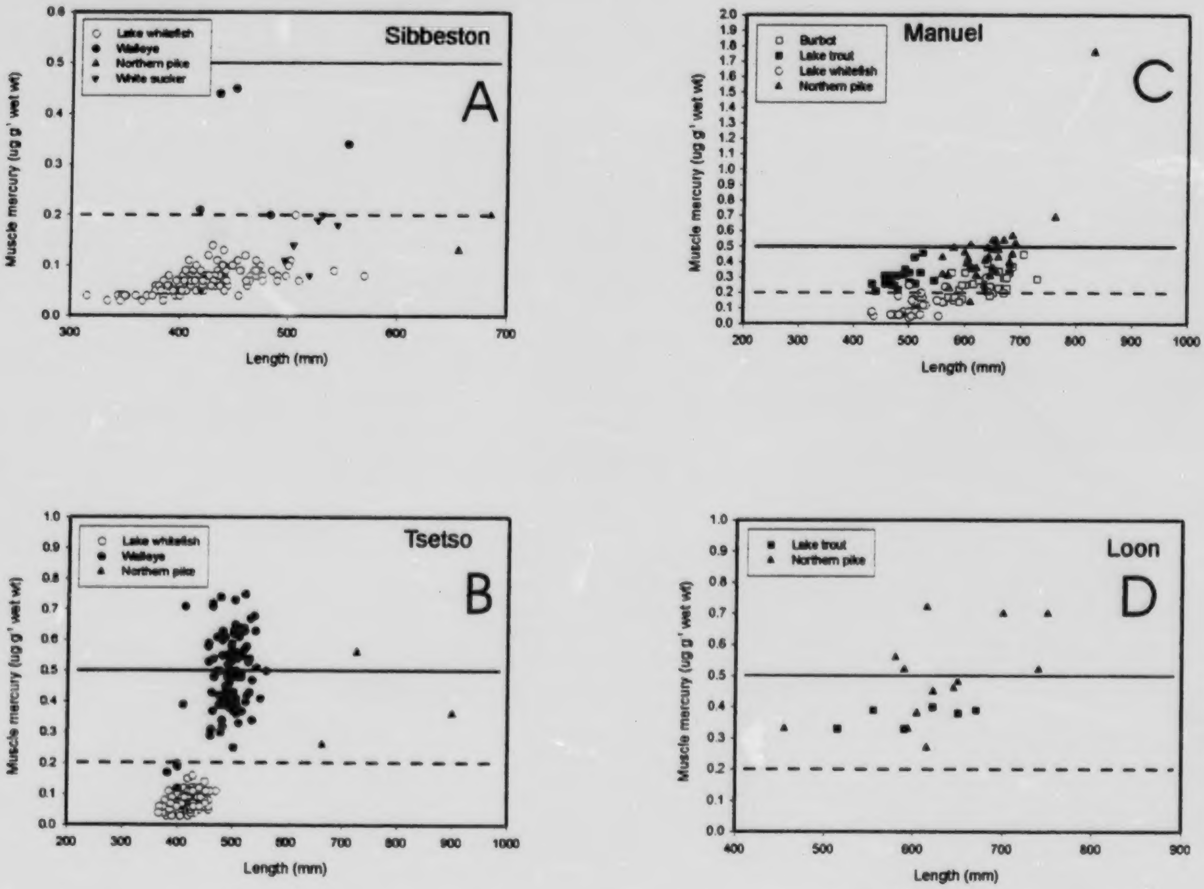

Figure 1. Muscle mercury concentrations in fish of varying length from Sibbeston (A), Tsetso (B), Manuel (C) and Loon lakes (D), NWT. The solid line at 0.5 µg·g⁻¹ mercury is the maximum recommended in fish for commercial sale and the dashed line at 0.2 µg·g⁻¹ is the maximum recommended in fish for subsistence.

Table 4. Summary statistics describing mercury levels in fish from Loon Lake.

Arithmetic mean calculations from SAS

Loon Lake		N	Arith. Mean	S.D.	Min	Max
Lake trout	Length	6	600.3	58.7	515	670
	Hg	6	0.370	0.032	0.330	0.400
Northern pike	Length	14	647.5	104.0	455	905
	Hg	14	0.506	0.149	0.270	0.720

Robust regression calculations from NCSS

Loon Lake		N	Mean S.D.	Intercept	Slope	R-squared
Lake trout	Hg	6	0.367 ± 0.026	0.127	0.000395	0.681*
Northern pike	Hg	14	0.487 ± 0.105	– 0.023	0.000785	0.547*

*Significant at 5 % probability level

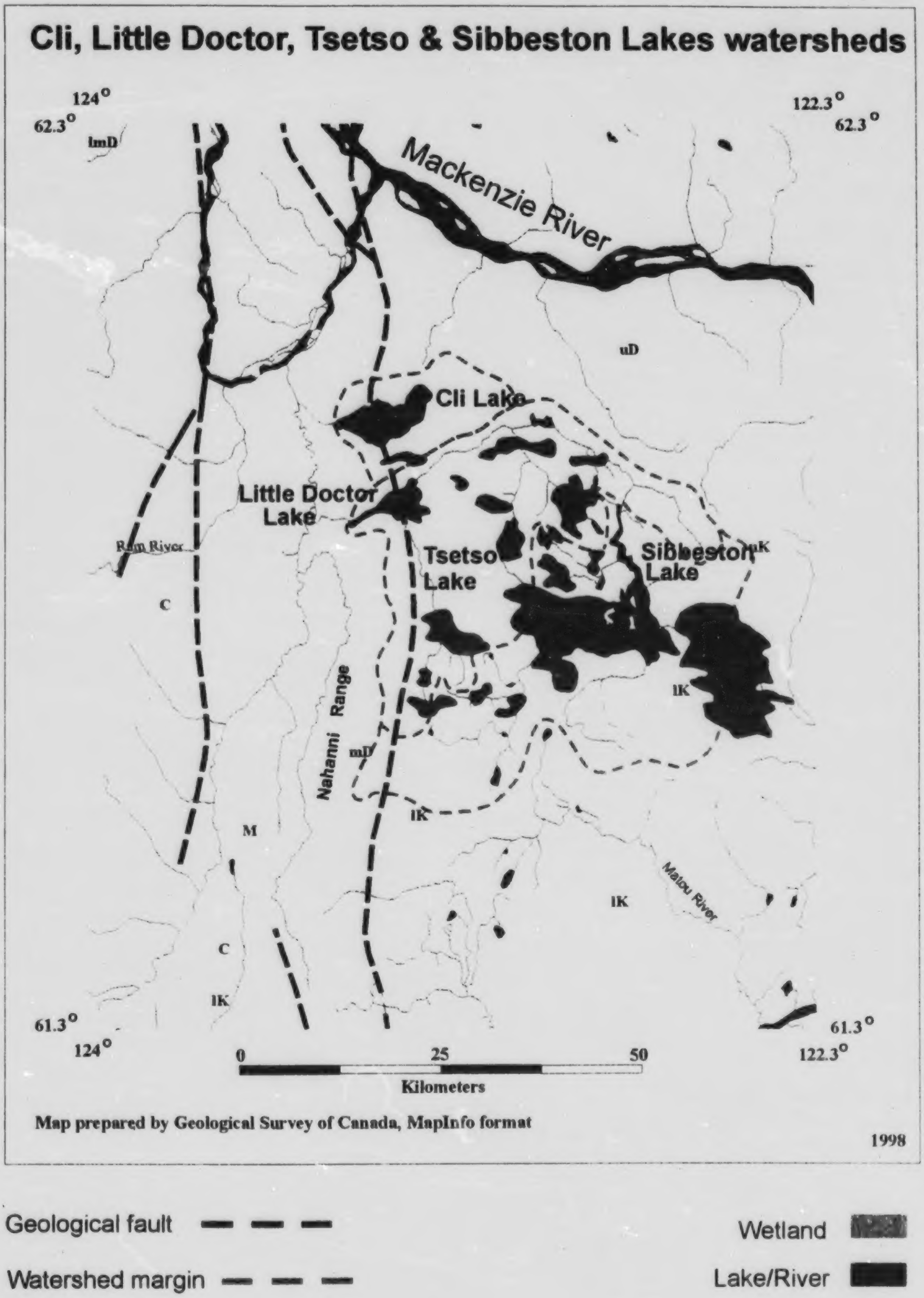
Cli, Little Doctor, Tsetso & Sibbeston Lakes watersheds
124°
62.3°
122.3°
62.3°
lmD
Mackenzie River
uD
Cli Lake
Little Doctor Lake
Tsetso Lake
Sibbeston Lake
uK
Ram River
C
lK
Nahanni Range
mD
lK
M
lK
Matou River
C
lK
61.3°
124°
61.3°
122.3°
0
25
50
Kilometers
Map prepared by Geological Survey of Canada, MapInfo format
1998
Geological fault
Watershed margin
Wetland
Lake/River

Figure 2. Approximate watershed boundaries, wetlands, and geological faults in the area of Cli, Little Doctor, Tsetso, and Sibbeston lakes, NWT

as has been hypothesized at Kaminak Lake (Shilts and Coker 1995). Data on fish from Sibbeston and Tsetso lakes are listed in Tables 1 and 2 while fish mercury concentrations from Cli and Little Doctor Lakes, as first presented by Muir and Lockhart (1997), are in Tables 5 and 6. Arithmetic mean values for mercury in lake whitefish for the four lakes were 0.085 (Cli), 0.131 (Little Doctor), 0.071 (Sibbeston) and 0.075 (Tsetso). Least squares adjusted means adjusting for differences in fish length (calculated using the LSMEANS option of PROC GLM of SAS) were 0.055 (Cli), 0.140 (Little Doctor), 0.075 (Sibbeston) and 0.079 (Tsetso). Differences among the lakes were highly significant ($F=36.35$, $p<0.0001$) even after the influences of fish length were accounted for. Cli and Little Doctor lakes differed statistically from each other and from both Sibbeston and Tsetso lakes, which did not differ from one another. The geological faults may well influence the levels of mercury in the fish, but it seems that the amount of influence differs between Cli and Little Doctor lakes. The simple presence or absence of the geological fault does not seem to provide an adequate explanation for the lake-to-lake differences. The lakes can be expected to differ in a number of other limnological features and efforts are underway in the project headed by Dr. M.S. Evans to discern the features regulating mercury in the fish in these lakes.

Relationship of mercury and selenium in the same fish

We have accumulated over 1000 assays of selenium and mercury in the same individual fish. These levels were examined for statistical correlations between mercury and selenium by comparing each species within a lake (Table 7). Of the 33 comparisons made in this way, only eight indicated a relationship between the two elements. Of the eight cases in which strong correlations existed, four were positive and four were negative. Some relationships between mercury and selenium were shown graphically for fish from the Mackenzie River and from several lakes (Rorey, Kelly, Yaya) in the previous report submitted for this project (Lockhart *et al.* 1999). Concentrations of mercury and selenium in fish from several lakes were tabulated in the *Canadian Arctic Contaminants Assessment Report* (CACAR: Jensen *et al.* 1997; p. 206). The mean mercury and selenium levels in Table 7 together with means reported in the CACAR report (where they are different) are shown together in Figure 3 and it is evident that there is no consistent association between these two elements in the fish.

The analysis presented above ignores effects of fish size which often affects levels of mercury. The General Linear Models procedure of SAS was applied to compare mercury levels in the nine groups of lake trout listed in Table 7, taking selenium and length and lake as potential influences. Important influences on mercury were derived from fish length ($F=114.76$, $p<0.0001$) and lake ($F=21.52$, $P<0.0001$) but not from selenium ($F=0.25$, $p=0.6147$). Similarly, for the three groups of arctic char, lake whitefish, and northern pike, the influence of selenium on mercury levels was not important after the effects of fish length and lake were taken into account. These data will be subject to further statistical analyses over the coming months.

DISCUSSION/CONCLUSIONS

There have been surprisingly few surveys of mercury levels in fish from the Northwest Territories or Nunavut. The most complete survey data are those of the Inspection Service of the DFO (now part of the Canadian Food Inspection Agency) but those data usually reflect quite small numbers of samples of fish per lake and are usually of restricted range in fish size. The Inspection data are unpublished although some of them were summarized in the CACAR report. There have been some studies of particular locations, for example, the systems containing Lac Ste. Therese (Stephens 1995) and Giauque Lake (Discovery gold mine; Moore and Sutherland 1980) but no broad geographical surveys. Lockhart *et al.* (1999) reported mercury levels in fish from 12 lakes in the NWT and Nunavut and concluded that a high proportion, perhaps half, of the lakes in the region must contain at least some fish with mercury levels over guidelines for human consumption.

Cli and Little Doctor lakes, which are situated on geological faults, had slightly higher mean levels of mercury in lake whitefish than the nearby Sibbeston and Tsetso lakes, which are not on the faults. Walleye from Little Doctor Lake had a relatively high mean mercury content of 0.778 $\mu g \cdot g^{-1}$ as compared with Sibbeston and Tsetso lakes where means were 0.330 and 0.475 $\mu g \cdot g^{-1}$, respectively. Northern pike numbers were quite small but seemed to fit the same pattern as walleye. The sucker species from Little Doctor Lake was not identified but the mean mercury level was 0.185 $\mu g \cdot g^{-1}$; if the species was the same as white sucker from Sibbeston Lake, then they may be compared. White suckers obtained from Sibbeston Lake had a mean mercury level of 0.141 $\mu g \cdot g^{-1}$. Overall, the differences among mean mercury levels from the lakes are small but consistently in the direction of slightly higher levels in the lakes on the faults than in the nearby lakes not on the faults. These are good choices for further scientific study to examine further their historical and limnological features to test rigorously whether the geological settings or other limnological differences can explain the differences in mercury levels in the fish.

Taking these results together with the unpublished data from the Inspection Service, there seems no doubt that

Table 5. Summary statistics describing mercury levels in fish from Cli Lake, a lake located on a geological fault.

Arithmetic mean calculations from SAS

Cli Lake		N	Arith. Mean	S.D.	Min	Max
Lake whitefish	Length	36	501.6	47.4	400	609
	Hg	36	0.085	0.029	0.050	0.160
Lake trout	Length	49	485.1	110.4	250	850
	Hg	49	0.876	0.791	0.20	4.61

Robust regression calculations from NCSS

Cli Lake		N*	Mean S.D.	Intercept	Slope	R-squared
Lake whitefish	Hg	36	0.076 ± 0.018	– 0.077	0.00031	0.410*
Lake trout	Hg	48	0.788 ± 0.485	– 1.713	0.00514	0.870*

*Significant at 5 % probability level

Table 6. Summary statistics describing mercury levels in fish from Little Doctor Lake, a lake located on a geological fault.

Arithmetic mean calculations from SAS

Little Doctor		N	Arith. Mean	S.D.	Min	Max
Lake whitefish	Length	18	406.9	25.7	365	450
	Hg	18	0.131	0.064	0.060	0.300
Walleye	Length	18	473.7	54.5	320	552
	Hg	18	0.753	0.291	0.210	1.27
Northern pike	Length	9	695.4	130.2	522	931
	Hg	10	0.771	0.367	0.410	1.48
Sucker	Length	6	491.0	52.4	420	560
	Hg	6	0.195	0.092	0.090	0.320
Lake trout	Length	10	547.3	42.3	458	607
	Hg	10	0.394	0.081	0.20	0.49

Robust regression calculations from NCSS

Little Doctor						
Lake whitefish	Hg	18/17	0.105 ± 0.031	– 0.342	0.00112	0.715*
Walleye	Hg	18/18	0.778 ± 0.227	– 0.553	0.00282	0.370*
Northern pike	Hg	10/5	0.609 ± 0.165	– 0.275	0.00138	0.999*
Sucker	Hg	6/6	0.185 ± 0.077	– 0.050	0.00048	0.089
Lake trout	Hg	10/10	0.383 ± 0.064	– 0.458	0.00152	0.769*

*Significant at 5 % probability level

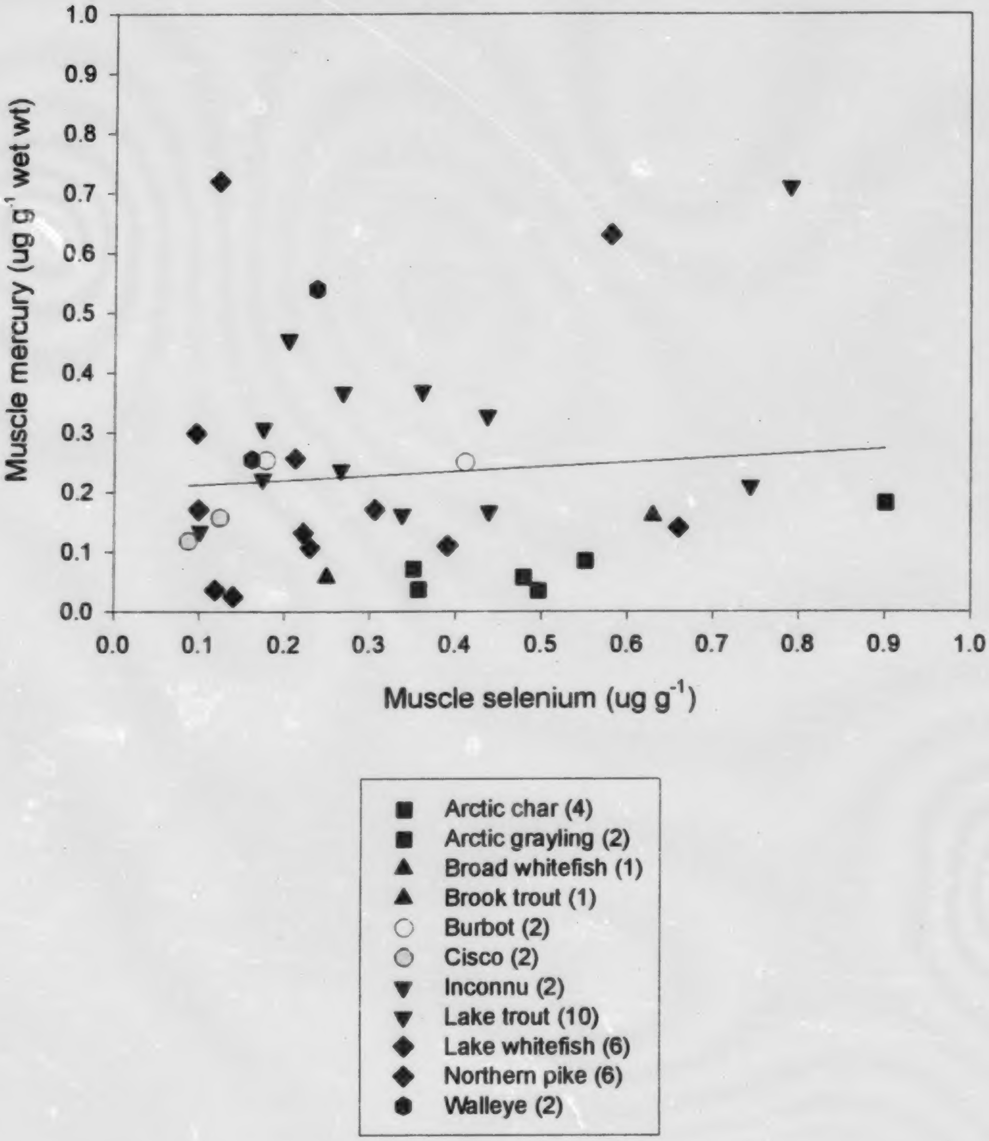

Figure 3. Mean mercury and selenium concentrations (µg·g^{-1} wet muscle) in catches of northern fish without regard for fish size or lake of origin. Means are taken from Table 7 and from the CACAR report (page 206) and represent pairs of analyses from over 1000 individual fish.

Table 7. Mean mercury and selenium concentrations in muscle of fish from northern lakes

Lake	Species	N	Mean Hg ($\mu g \cdot g^{-1}$)	Mean Se ($\mu g \cdot g^{-1}$)	Correlation Hg *vs.* Se	Significance
Belot	Lake trout	19	0.135	0.101	+ 0.594	0.0074
Colville	Lake trout	10	0.308	0.175	+ 0.580	0.079 (n.s.)*
Hawk	Lake trout	9	0.238	0.266	+ 0.409	0.274 (n.s.)
Koksoak R.	Lake trout	8	0.369	0.361	+ 0.784	0.021
Mahoney	Lake trout	20	0.368	0.268	+ 0.721	0.0003
P+N	Lake trout	9	0.328	0.437	+ 0.660	0.053 (n.s.)
Rorey	Lake trout	48	0.456	0.204	+ 0.401	0.0047
Saturday Night	Lake trout	15	0.223	0.174	+ 0.038	0.892 (n.s.)
Yaya	Lake trout	28	0.210	0.744	– 0.803	0.0001
Colville	Lake whitefish	24	0.025	0.140	– 0.033	0.878 (n.s.)
Mackenzie R.	Lake whitefish	7	0.110	0.391	+ 0.193	0.678 (n.s.)
Mahoney	Lake whitefish	20	0.132	0.222	– 0.261	0.266 (n.s.)
Manuel	Lake whitefish	27	0.107	0.230	+ 0.094	0.641 (n.s.)
Tagatui	Lake whitefish	20	0.036	0.119	– 0.651	0.0019
Ekali	Walleye	14	0.255	0.161	– 0.256	0.377 (n.s.)
Sanguez	Walleye	20	0.540	0.237	+ 0.323	0.165 (n.s.)
Ekali	Northern pike	7	0.299	0.096	– 0.154	0.742 (n.s.)
Mackenzie R.	Northern pike	12	0.171	0.306	– 0.097	0.349 (n.s.)
Mahoney	Northern pike	20	0.257	0.212	– 0.002	0.992 (n.s.)
Sanguez	Northern pike	20	0.720	0.122	– 0.191	0.419 (n.s.)
Tagatui	Northern pike	16	0.171	0.099	– 0.229	0.393 (n.s.)
Mackenzie R.	Broad whitefish	140	0.057	0.250	– 0.126	0.137 (n.s.)
Buchanan	Arctic char	19	0.037	0.358	– 0.703	0.0008
Hazen	Arctic char	45	0.182	0.902	+ 0.088	0.565 (n.s.)
P+N	Arctic char	15	0.085	0.552	– 0.548	0.034
Mackenzie R.	Arctic grayling	20	0.072	0.352	+ 0.005	0.983 (n.s.)
Nahanni R.	Arctic grayling	12	0.036	0.497	– 0.232	0.468 (n.s.)
Ekali	Cisco	20	0.119	0.087	– 0.010	0.967 (n.s.)
Sanguez	Cisco	12	0.158	0.124	+ 0.359	0.253 (n.s.)
Mackenzie R.	Burbot	31	0.250	0.411	+ 0.159	0.394 (n.s.)
Manuel	Burbot	23	0.254	0.178	+ 0.343	0.110 (n.s.)
Mackenzie R.	Inconnu	81	0.163	0.338	– 0.118	0.294 (n.s.)
Yaya	Inconnu	30	0.168	0.439	+ 0.122	0.520 (n.s.)

*correlation not statistically significant at the 5 % probability level

a wide range of lakes in the NWT and Nunavut contain at least some fish which exceed the 0.5 $\mu g \cdot g^{-1}$ mercury level used to regulate the sale of commercial fish. Obviously an even larger proportion of lakes contain fish with levels over 0.2 $\mu g \cdot g^{-1}$, the maximum recommended for subsistence users who consume a lot of fish. The role, if any, of selenium in the fish in regulating mercury in the same fish is ambiguous. Sometimes the two elements in the fish are correlated and sometimes they are not. The measurement of selenium in the environment may have a more important role in regulating mercury in the fish than selenium measured in the fish. The presence of geological faults in two of the lakes offers an opportunity to test whether those features may be associated with mercury in the fish. The comparison present to date suggests that there may well be a relationship but that it is relatively small in comparison with other factors regulating mercury in the fish.

Expected Project Completion Date: Ongoing, as long as local resource management agencies want additional lakes examined or want additional data on lakes already in use. While the focus for lake selection addresses questions raised by local communities, the scientific focus in on trying to understand the environmental features of the systems that may control the levels of mercury to the fish.

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MERCURY TOXICOLOGY IN BELUGA WHALES

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Project Team: Hunters and hunt monitors of the Hendrickson Island beluga hunt

OBJECTIVES

1. To examine organs and tissues of beluga whales for indications of effects of mercury.

DESCRIPTION

Beluga whales are consumers of fish and there is abundant evidence of widespread accumulation of mercury in several other species of fish-eating marine mammals such as ringed seal and narwhal. There has been virtually no study of the toxicology of mercury in these animals although our recent work with beluga whales from the Mackenzie Delta has shown high levels of mercury in blood and brain (Hyatt *et al.* 1996). Blood levels of mercury have been used to assess the risks associated with mercury in humans and the blood levels in the whales are in the range designated as the highest risk category in people. Mercury is a neurotoxin and there were no previous reports of mercury in brain of northern marine mammals prior to this study. Some beluga had brain levels that would be high enough to poison some species of laboratory test animals. Regarding effects on beluga, laboratory dosage/ response studies with *in vitro* exposures of tissue to mercury are just being completed (Fournier *et al.* unpublished) and indicate that effects can be anticipated at realistic levels.

ACTIVITIES IN 1998/99

There were no field or laboratory activities in 1998/99. A poster presentation was prepared for the 5th International Conference on Mercury as a Global Pollutant in Rio de Janeiro in May, 1999 (Hyatt *et al.* 1999). Also, the thesis by Ms. Hyatt is being written and will be submitted to the University of Manitoba before October 2000.

RESULTS

Organs from beluga collected at Hendrickson Island by hunters from Inuvik, Aklavik and Tuktoyaktuk were obtained for mercury analyses. Most of the results were reported by Hyatt *et al.* (1999) at the Rio conference on mercury and the results presented below are taken from that poster presentation. The results of total mercury analysis of whole blood are shown in Figure 1. It is evident that whale blood levels consistently exceed the human blood 'at risk' level of 100 $ng \cdot g^{-1}$ although the implications of this level for the whales is unknown.

Since the whales are generally shot at sea and towed to shore for flensing and sampling, it was of interest to determine whether blood from live whales have the same mercury content as blood sampled from the dead whales. Blood fractionates and clots when it sits still, therefore, it is more difficult to obtain a uniform sample from blood that has not been kept well mixed by the circulation in a live animal. This could potentially bias the samples, since most of the whales were dead when the blood samples were received . The opportunity to test for such a bias came in 1995 when a whale tagging program was being conducted at the same time. Blood from tail flukes of live whales was obtained (courtesy of Jack Orr, DFO, Winnipeg) and the mercury levels for it are shown in Figure 1 as red points. Mercury concentrations in the blood of live whales were in the same range as in the blood from dead whales, so the values from the dead whales probably do give a good representation of levels when they were still alive.

Most of the mercury in blood was associated with the blood cells, not with the plasma (Figure 2). The predominant form of mercury in the blood was methylmercury (Figure 3). All of the organic mercury was methylmercury. There was no statistical relationship between mercury and selenium in blood.

Concentrations of mercury in brain and spinal cord were much higher than in blood but the proportions represented by organic forms were much lower (Figure 4). Also, there appears to be an organic form of mercury other than methylmercury.

There was a strong statistical relationship between mercury and selenium in several body organs, although not in blood or muktuk (Lockhart *et al.* 1999). This may

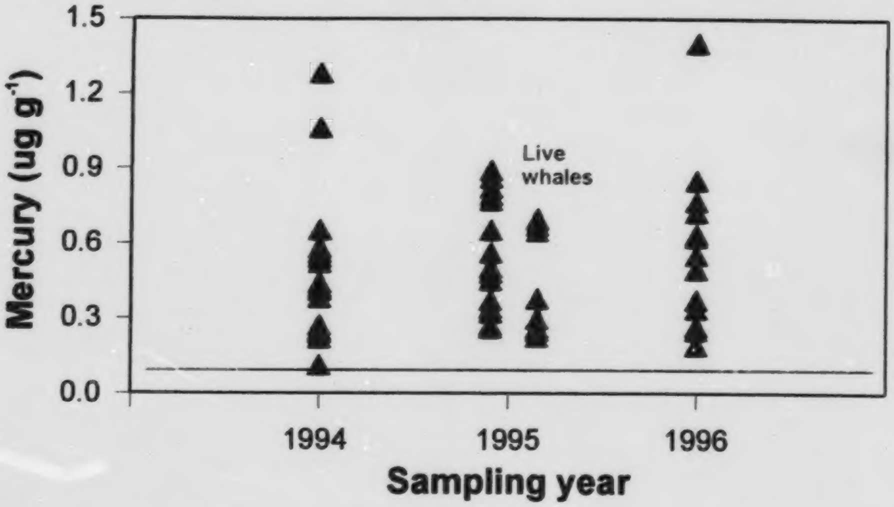

Figure 1. Beluga whale whole blood total mercury (µg·g^{-1}) Mackenzie Delta whales, 1994–1996. The level described as 'at risk' in human blood is shown as a red line at 0.1 µg·g^{-1}.

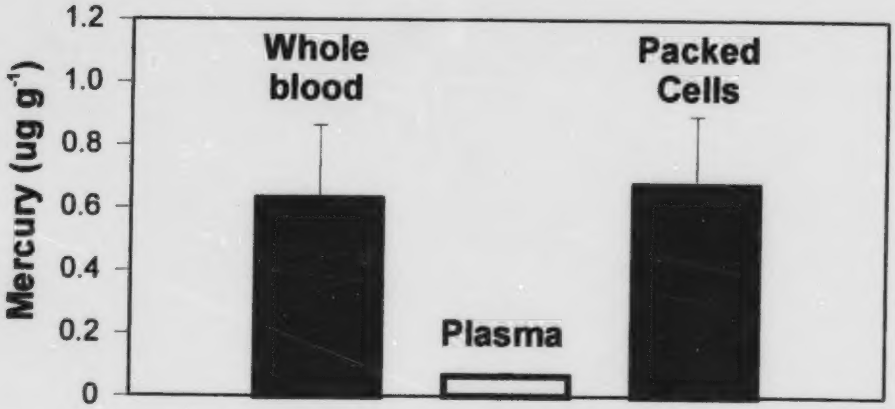

Figure 2. Total mercury in beluga blood components, Mackenzie Delta. 1995.

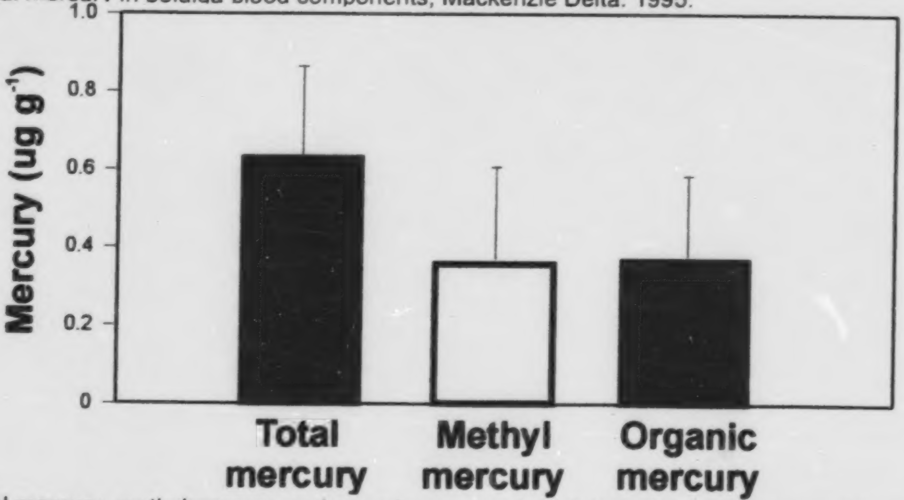

Figure 3. Total mercury, methylmercury, and organic mercury (which includes methylmercury) in whole beluga whale blood.

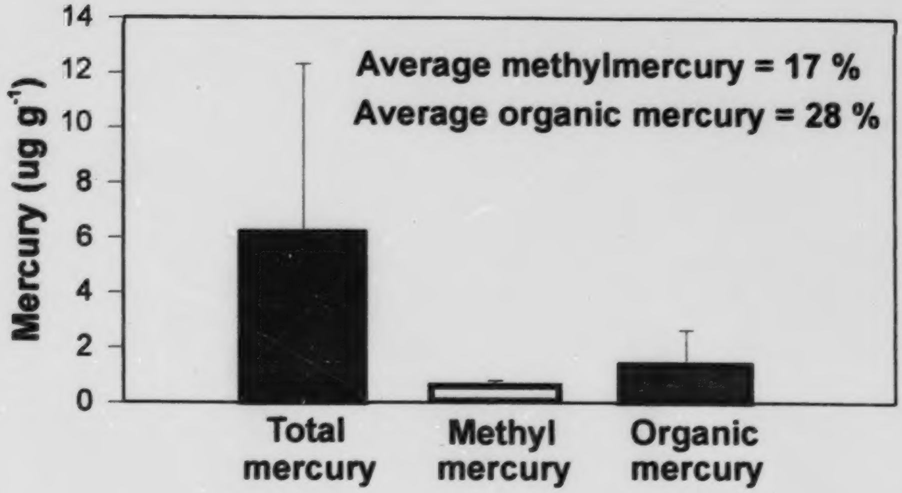

Figure 4. Total mercury, methylmercury, and organic mercury (which includes methylmercury) in brain of beluga whales, Mackenzie Delta, 1995.

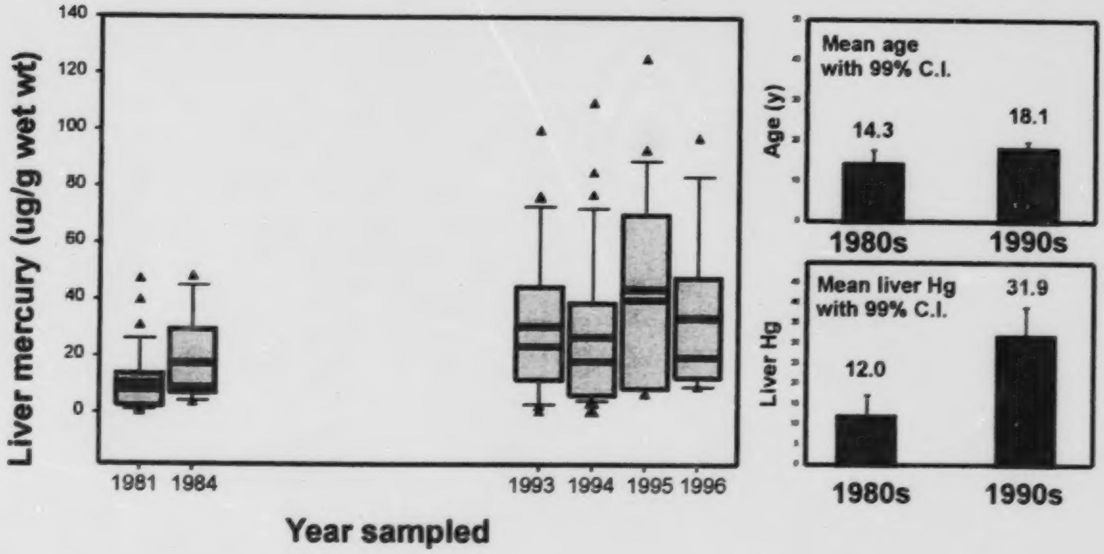

Figure 5. Mercury in beluga liver from whales taken in the western Arctic in the 1980s and 1990s.

imply storage of mercury as a selenide similar to that reported in striped dolphins (Nigro 1994). It is striking that the organs lacking a relationship between mercury and selenium are those in which the predominant form of mercury is methylmercury.

Collections of whale organs from the western Beaufort date from the early 1980s. Wagemann *et al.* (1996) compared mercury levels in beluga from collections in 1981-84 with those from 1993-94 as functions of whale age. The present data allow the extension of the data from the 1990s to include the whales taken in 1995 and 1996. Data for liver are shown in Figure 5.

The most recent data confirm higher levels of mercury in the whales from the 1990s. Whales taken in the 1990s were older (18.1 years) than those from the 1980s (14.3 years). Wagemann *et al.* (1996) derived the expression: Hg = -6.28 +1.31 x age, which suggests that the difference in age might be responsible for an increase from 12 to 17 $\mu g \cdot g^{-1}$ but not for the observed increase from 12 to 32 $\mu g \cdot g^{-1}$. Independent studies of mercury in beluga comparing levels in modern teeth and teeth several hundred years old also suggest that levels have increased over time, although possible differences in ages of the pre-industrial and modern harvested animals make it difficult to state the degree of increase without ageing studies on the pre-industrial animals (Outridge *et al.* 1999, pers. comm.). Recently, Braune (1999) has identified a similar trend in sea bird eggs. Lake sediment cores have also indicated increasing inputs of mercury to the Arctic (Lockhart *et al.* 1998).

DISCUSSION/CONCLUSIONS

It has been known since the 1980s that levels of mercury in some beluga organs (e.g. liver, kidney) are high relative to human consumption guidelines (see Wagemann *et al.* 1996, for data from the 1980s and 1990s). Risk of methylmercury poisoning in humans is assessed from levels measured in blood or hair. There has been no prior information on mercury in the blood of arctic whales. Methylmercury is a neurotoxin and there has similarly been no information available on levels in brain or spinal cord in arctic whales. Our first indications that blood and brain levels were high were reported by Hyatt *et al.* (1996) and by Lockhart *et al.* (1997). Subsequent measurements have confirmed the high levels. If whales respond as other species (e.g. cats, Charbonneau *et al.* 1974), there is enough mercury in some whales to cause biological injury. However, methylmercury is the neurotoxic form of mercury and whale brain and spinal cord contain relatively little methylmercury as a proportion of total mercury. Since methylmercury is the predominant form in blood and since the source of mercury to brain and spinal cord is likely to be blood, it appears that the neurological organs must change the form of mercury from that delivered to that stored.

The tight correlation between mercury and selenium in most organs other than blood and muktuk suggests that whale organs may store mercury as a selenide. We reported earlier (Hyatt *et al.* 1996, Lockhart *et al.* 1997) that liver slides contain dark staining objects in macrophages and these resemble deposits of mercuric selenide identified in other species (Nigro 1994). Whales with high mercury levels contain more of these than whales with low mercury levels. The most complete description of the speciation of mercury in arctic marine mammals was reported by Wagemann *et al.* (1999; see also Lockhart *et al.* speciation project report in this issue) working with liver. Based on a fractionation procedure, these studies identified mercuric selenide as a dominant form of mercury.

The intent of this project was to evaluate the toxicology risk of mercury for the whales. The data show that the whales accumulate high levels of mercury in several body organs including brain and spinal cord. However, the species of mercury present suggest that the whales may detoxify mercury by demethylating it and storing it as an inert mineral form, namely mercuric selenide. More definitive proof of this will have to derive from experimental studies of the metabolic processing of methylmercury by whale organs. If this hypothesis is correct, it may represent an adaptation to allow the whales to survive in spite of accumulations of mercury. The most disturbing aspect of the data is the apparent increase in the amounts of mercury in the whales. If a detoxification mechanism exists in whale organs, then one wonders at what level it becomes saturated. One also wonders whether this mechanism is present in other animals, even people.

Expected Project Completion Date: The project is complete except for final thesis preparation and publication.

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METHYLMERCURY AND MERCURY SPECIATION IN ARCTIC PEOPLE AND MARINE MAMMALS

Project Leaders:

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Project Team: Gail Boila, DFO, Winnipeg, MB

OBJECTIVES

1. In the short term, to focus on identifying the species of mercury present in liver of humans and in liver and brain of marine mammals (ringed seals). In the longer term, to definitively identify all the different mercury species in target organs of people and top predator arctic animals.
2. To assess the data in relation to human and animal health and human consumption guidelines.
3. To measure methylmercury (MeHg), selenium and organo-mercurials (other than MeHg) concentrations in tissues of marine mammals (beluga, walrus, bearded seals and harp seals) and to provide a consistent data base for dietary intake and health risk/benefit calculations across the Canadian Arctic, in support of Aboriginal peoples' dietary studies and for future spatial and temporal trend analyses.

DESCRIPTION

Preliminary data indicate that the total Hg concentration in beluga liver and brain tissue may not be a good indicator of mercury's toxicity to the animals or possibly to consumers of those animals since much of the mercury appears to be in combination with selenium and probably rendered inert. Martoja and Berry (1980) have identified 15-nm sized mercuric selenide granules in livers of cetaceans from the Mediterranean Sea. This mercuric selenide (tiemannite) is non-toxic, but also non-biodegradable since mercury bound to selenium cannot be re-metabolized. Because of this, they have found that the amount of tiemannite trapped in the liver increased with the age of the animals. More recent developments in analytical methods have also confirmed the formation of an inorganic Hg-Se complex in dolphin livers as being cationic, water-soluble, low-weight, and different from *bis*(methylmercuric)selenide (Shibata *et al.* 1992). Finally, Nigro (1994) has definitively identified the presence of an inert mercuric selenide compound in dolphins, and Hyatt *et al.* (1996) and Lockhart *et al.* (1997) identified numerous dark granules possibly composed of mercuric selenide in macrophages of highly-mercury-contaminated beluga livers. Previous research on humans has found 12-nm sized particles composed of mercury and selenium in macrophages of workers occupationally exposed to mercury (Kennedy *et al.* 1977), but the mechanisms of detoxification were less understood at the time and the particles were not formally identified as mercuric selenide, albeit Hg:Se ratios measured were close to 1.

In sea mammals, the total mercury burden in organs (including brain) appears to be made up of at least four different categories of mercury species of which mercuric selenide (HgSe) appears to be the largest (50% or more). In addition to MeHg, another form (or forms) of organic mercury, which is probably toxic, appears to be present in the liver and brain.

Given the fact that mercury exposure is a priority health issue among northern Aboriginal communities, it is of utmost interest to examine the possibility that the mercury stored in human livers might also be present in its detoxified selenide form. This could shed new light on human detoxification mechanisms and on the importance of selenium ingestion to account for effect differences in human health research undertaken in different populations.

ACTIVITIES IN 1998/99

During 1998/99, we analysed previously collected beluga whale tissue to determine the species of mercury present in them. We also planned to analyse some samples of human tissues obtained from Greenland for the types of mercury present in them, however, those analyses have been delayed due to the small size of the samples and their late arrival in Canada. Both human and whale tissues were also to be examined microscopically for indications of the presence and/or effects of mercury.

RESULTS

a) Fractionation procedure used to identify mercury species

The fundamental aspect of this project is the fractionation procedure used to identify the major species of mercury present. This procedure was described in detail in a presentation made at the International Conference on Mercury as a Global Pollutant in Rio de Janeiro in May (Wagemann *et al.* 1999) and a version of the analytical section of that paper is included below. An overview of the procedure is also presented as a flow chart in Figure 1. The procedure distinguishes four types of mercury species: methylmercury; organic mercury other than methylmercury; inorganic mercury; and an insoluble form of mercury, deemed to be mercuric selenide (HgSe).

Total mercury

A quantity of tissue (~0.2 g) was digested with a mixture of nitric and sulfuric acids (1:4 v/v) for 2 hours at 90°C, cooled, then potassium permanganate (15 mL, 6% aqueous) was added and the digest was allowed to stand overnight. The solution was clarified by the dropwise addition of 30% hydrogen peroxide while vortexing, and made up to 25 mL volume. Total mercury was determined by cold-vapour atomic absorption spectroscopy (CVAAS), using the air-segmented, flow-injection method (Armstrong and Uthe 1971). A TM 3200 (TSP Thermo Separation Products) mercury monitor was used. Data were recorded with a "Chrom Jet Integrator" (TSP Thermo Separation Products). Aqueous working standards (1-10 µg·L^{-1}) were prepared daily from a "Baker instra-analysed" 1000 µg·mL^{-1} Hg stock solution. The detection limit for Hg by the CVAAS method under the operating conditions employed was 5 ng·g^{-1} wet weight.

Organic mercury

The release of MeHg and other forms of organic mercury from the tissues was achieved by the commonly used procedure of Uthe et al. (1972). Approximately 1 g of wet tissue was homogenized with an aqueous solution of acidic sodium bromide (5 mL of 30 % in 4 N H_2SO_4) and cupric sulfate (7.5 mL of 2.5 % in 4 N H_2SO_4). MeHg and other forms of organic mercury were then extracted by vortexing the tissue homogenate with a 3:2 v/v mixture of DMC (dichloromethane)-hexane (5-10 mL) followed by centrifugation to separate the organic and aqueous layers from the solid material (pellet). The density of the DMC-hexane mixture was such that the organic layer separated uppermost. An aliquot (1 mL) of the organic phase was withdrawn, added to a test tube containing 5 mL of HNO_3/H_2SO_4 mixture (1:4 v/v) and heated for 30 minutes at 60°C. The organic solvent mixture evaporated without detectable loss of organic Hg. The remaining aqueous phase was digested and analysed as for total mercury. The detection limit for organic mercury by this method was 10 ng·g^{-1} of tissue (wet weight).

Organic mercury other than methylmercury

Organic mercury, as such, included MeHg. The MeHg concentration, obtained separately, was subtracted from the organic mercury to obtain the quantity called "organic mercury other than methylmercury".

Methylmercury

The acidic sodium bromide and cupric sulfate tissue homogenate was extracted with DMC-hexane or toluene, and separated as described under "Organic Mercury". A fraction of the organic layer was withdrawn (2 mL) and extracted with (3-4 mL) aqueous thiosulfate (0.005 N aq. $Na_2S_2O_3$) by vortexing for 1 minute and centrifuging. To the separated thiosulfate aliquot (1-2 mL), KI (0.5 mL, 3 M aqueous) was added, and this solution was then back-extracted (vortexed for 1 minute) with toluene (1.5-3.0 mL). The toluene was separated by centrifuging for 2 minutes at 2500 rpm. The extract was dried over anhydrous sodium sulfate and injected (1 µL) into the GC column for MeHg analysis.

A Varian model 3400 gas chromatograph with a ^{63}Ni electron capture detector (ECD), temperature programmable injector (SPI), and a 5 m, SPB-5 mega-bore column (0.53 mm ID) with a bonded film (5 µm) of polysiloxane (94% dimethyl, 5% diphenyl, 1% vinyl) was used. The carrier gas was helium (12 mL/minute), and the make-up gas nitrogen (28 mL/minute). The temperature of the column and injector was maintained at 50°C for 1 minute, programmed to increase to 240°C (at 20°C/minute), and maintained at this temperature for 15 minutes before the cycle was repeated. The detector was maintained at 300°C at all times.

Working MeHg standards (5-100 ng·mL^{-1} Hg in toluene) for GC analysis were prepared daily from a toluene/MeHg stock solution (1 µg·mL^{-1} Hg). Within the concentration range of the working standards, the ECD response was linear. The absolute detection limit for CH_3HgI by GC-ECD was 2 pg (based on 3x S.D. of blank analyses), or 10-80 ng·g^{-1} Hg wet weight (depending on dilution factor) in terms of the procedure used.

Inorganic mercury

As described under "*Organic Mercury*", the simultaneous extraction of liver tissue with aqueous and organic solvents produced three distinct phases after

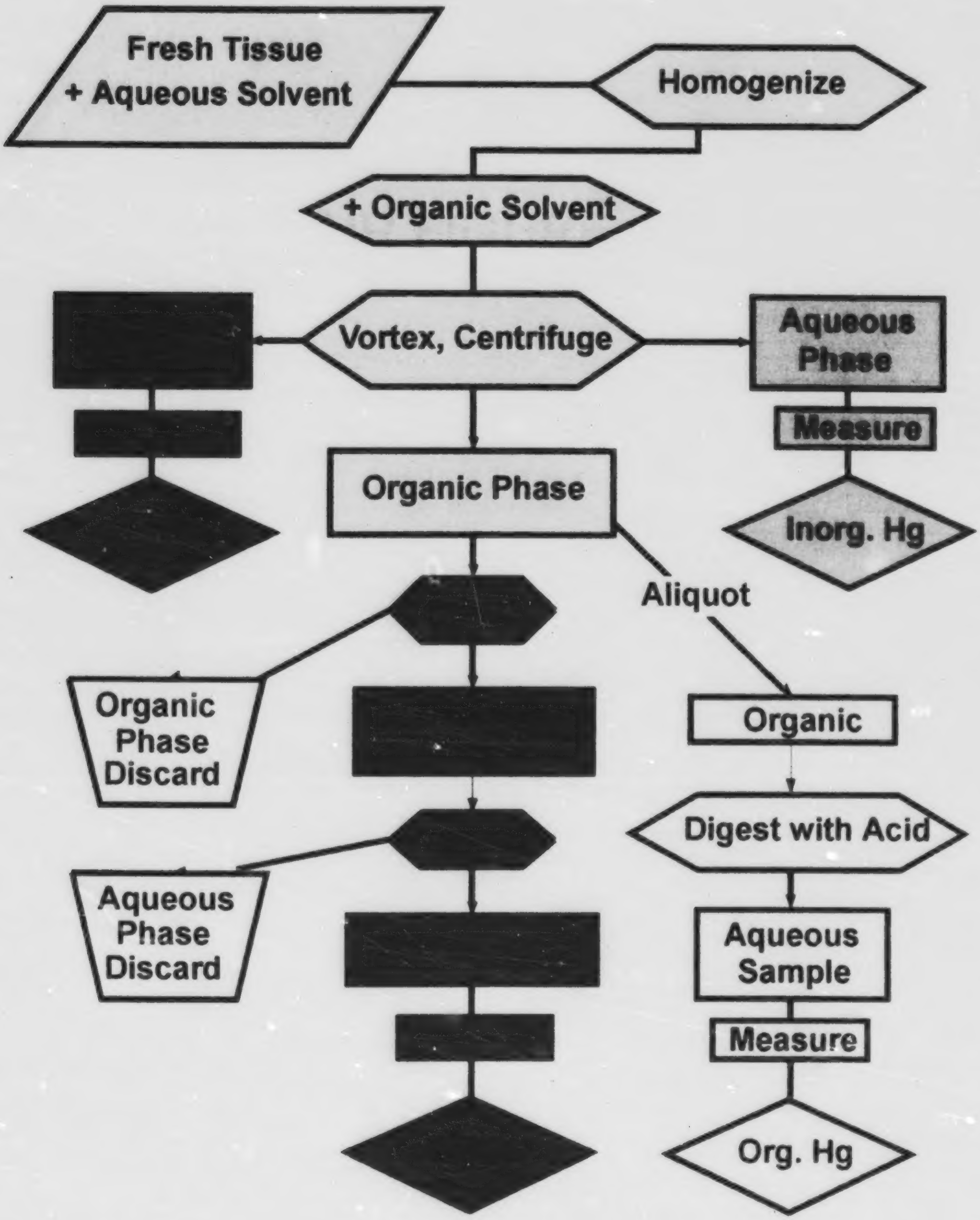
Fresh Tissue
+ Aqueous Solvent
Homogenize
+ Organic Solvent
Vortex, Centrifuge
Aqueous Phase
Measure
Inorg. Hg
Organic Phase
Aliquot
Organic Phase Discard
Organic
Digest with Acid
Aqueous Phase Discard
Aqueous Sample
Measure
Org. Hg

Figure 1. Procedure used to fractionate mercury species in beluga tissue.

Table 1. Mercury species in beluga whale liver ($\mu g \cdot g^{-1}$ expressed as mercury, wet weight).

Sample	Inorganic Hg	HgSe	MeHg	Organic Hg	Organic MeHg	Sum of species	Total Hg
HI-94-4	10.43	19.71	3.32	9.67	6.35	39.81	37.83
HI-94-7	17.92	33.86	3.09	11.52	8.43	63.30	64.13
HI-94-12	29.64	59.30	4.86	33.49	28.63	122.43	113.07
HI-94-24	15.29	27.28	2.73	12.39	9.66	54.96	44.71
HI-94-27	21.91	42.42	5.43	13.26	7.83	77.59	79.06
HI-94-10	9.87	23.44	1.16	7.16	6.00	40.47	45.19
HI-94-14	9.56	30.64	3.06	10.35	7.29	50.55	43.74
HI-94-15	7.35	15.08	3.03	11.29	8.26	33.72	34.24
HI-94-16	19.43	37.85	3.56	15.34	11.78	72.61	72.59
HI-94-21	24.40	44.01	6.13	28.27	22.14	96.68	84.67
HI-94-29	14.62	39.89	4.46	21.57	17.11	76.08	74.25
HI-94-6	32.43	52.50	3.48	25.45	21.97	110.38	109.24
HI-94-8	6.71	11.36	2.40	5.01	2.61	23.08	21.90
HI-94-25	8.30	22.96	1.04	6.74	5.70	38.00	37.50
EWF-94-4	22.41	25.35	3.81	9.97	6.16	57.73	58.47
EWF-94-12	18.78	31.66	4.59	12.32	7.73	62.76	56.67
EWF-94-7	0.03	0.05	0.32	0.38	0.06	0.46	0.47
EWF-94-9	1.22	2.42	0.56	1.57	1.01	5.20	4.53
EWF-94-14	6.06	10.37	1.82	4.96	3.14	21.38	18.44
CH-93-1	3.68	6.80	1.33	2.04	0.71	12.52	13.90
CH-93-9	1.20	2.16	1.00	1.67	0.67	5.03	4.78
CH-93-10	1.04	2.07	0.99	1.40	0.41	4.51	4.67
CH-93-12	1.21	2.86	1.31	2.13	0.82	6.20	5.20
CH-93-17	3.20	5.65	1.39	3.64	2.25	12.49	9.79
CH-93-19	1.25	3.09	1.04	1.50	0.46	5.84	5.03
CH-93-20	1.53	2.78	1.37	1.91	0.54	6.22	5.46
CH-93-30	1.10	2.62	0.82	1.23	0.41	4.95	4.83
CH-93-11	0.74	2.21	1.06	1.84	0.78	4.79	4.63
SQ-94-6	3.64	8.53	1.46	4.04	2.58	16.21	13.87
SQ-94-18	3.99	8.13	1.47	2.40	0.93	14.52	12.48
SQ-94-21	2.07	4.52	0.95	1.80	0.85	8.39	6.35
SQ-94-30	1.31	1.70	0.99	1.26	0.27	4.27	4.04
Arithmetic mean	9.45	18.23	2.31	8.36	6.05	36.04	34.24
Mean percent of Sum of species	26.2	50.6	6.4		16.8		

centrifugation: an upper organic layer, an aqueous bottom layer and a solid pellet. The mercury remaining in the aqueous layer after removal of the organic layer was considered to contain only inorganic mercury including mercury bound by sulfhydryl groups. The relatively high concentration of cupric ions in the extraction medium released the mercury bound by sulfhydryl groups. A 0.5 mL aliquot of the aqueous layer was withdrawn, digested and analysed for mercury as described under "*Total Mercury*".

Selenium

Fresh, whole liver tissue and extracted liver tissue (pellet) were analysed for selenium. Essentially the semi-automatic borohydride method of Vijan and Wood (1976) was used. Tissue samples (or pellets) were digested with nitric, perchloric and sulfuric acids (4:1:0.5 v/v), and the resulting digest was diluted with hydrochloric acid and water to 30% hydrochloric acid. The diluted digest and reductant (2% borohydride solution) were combined at flow rates of 4 and 1 mL/minute respectively, using a Technicon pump, Model III, coupled to a Varian programmable Model 55 sampler. The hydride was decomposed in a heated quartz tube and the selenium was analysed at a wavelength of 196.1 nm using a Varian Spectra AA-20 Atomic Absorption Spectrometer. The separated aqueous tissue extract was not analysed for Se due to analytical interference from the relatively high concentration of copper in the aqueous extract. Due to the very low solubility of mercuric selenide (CRC Handbook 1982-1983, Smith and Martell 1976, Wagemann *et al.* 1997), this compound if present would remain in the tissue pellet after extraction of the tissue with the aqueous acidic sodium bromide and cupric sulfate solution and the organic solvent mixture. The mercury and selenium found in the pellet after extraction was assumed to originate from mercuric selenide when the stoichiometric ratio was 1 between these two elements. This was reinforced by the known presence of mercuric selenide in liver tissue of marine mammals (Martoja and Berry 1980, Nigro 1994).

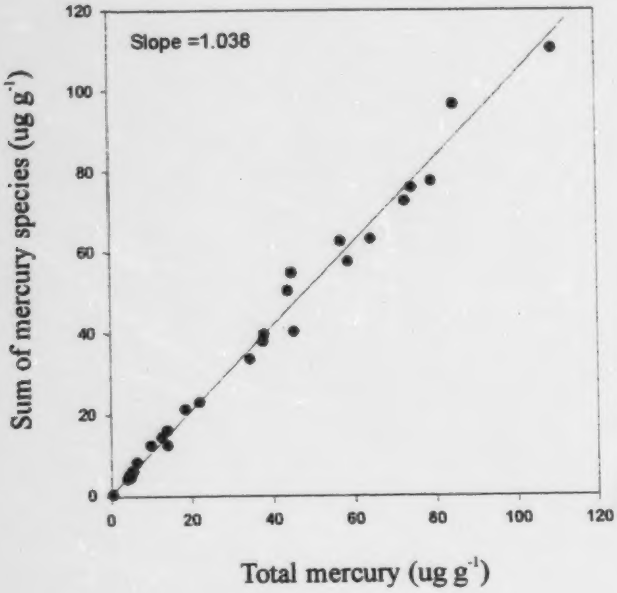

Figure 2. Mercury calculated as the sum of the four species identified as compared with the independent measurement of total mercury.

b) Results from the ecosystem component on whale tissue analyses

The individual results for the beluga liver are listed in Table 1. All four species of mercury were identified in each sample and there was an independent analysis for total mercury. If the four species identified by these extraction procedures include all of the mercury, then the sum of the four species should equal the independent measurement of total mercury. Inspection of Table 1 confirms the close agreement between the sum of the species and the measurement of total mercury. The sum of the species has been plotted against total mercury in Figure 2; the agreement between these two values extends over the full range of values and the slope was 1.

The average proportions of the four species of mercury are shown in Figure 3. The predominant form of mercury identified was HgSe, which comprised just over 50% of the total. Smaller proportions were represented by inorganic Hg (26%) and an organic form other than methylmercury (17%). Only a small portion of the liver mercury (average 6%) was composed of methylmercury. However, when the proportions of each of the four species are examined as a function of total mercury (Figure 4), it appears that the predominant form of mercury shifts from methylmercury at very low total mercury concentrations (Figure 4C) towards more inorganic mercury and HgSe at higher concentrations. We have only one sample where the total mercury was less than 1 $\mu g \cdot g^{-1}$, but in that sample, almost 70% of the mercury was present as methylmercury and only 11% as HgSe. Several other samples had relatively low total mercury levels (1–5 $\mu g \cdot g^{-1}$) and they also had relatively high proportions present as methylmercury (11-23%). This pattern is similar to the brain data which Hyatt *et al.* (1996) suggested might indicate a detoxification mechanism which becomes increasingly active when total mercury concentrations exceed a few $\mu g \cdot g^{-1}$.

c) Results from the human health component on human tissue analyses

The results on the human samples have been delayed due to the small size of the samples and their late arrival. Results will be incorporated into a later revision or into the report for next year.

DISCUSSION/CONCLUSIONS

The beluga whale results show clearly that there are several forms of mercury present in the beluga tissues with the predominant one in liver showing properties consistent with those of mercuric selenide. The fact that the four forms identified add up to the same amount as the independent measurement of total mercury argues that these four forms account for all the mercury. Speciation work in blood of beluga (Lockhart *et al.* this volume) has shown that the dominant form there is methylmercury and so the deep organs must change the form of mercury from that supplied by the blood to that found in the organs. This probably represents a net reduction in toxicity since methylmercury is regarded as the most toxic form. This would be consistent with higher proportions of forms other than methylmercury

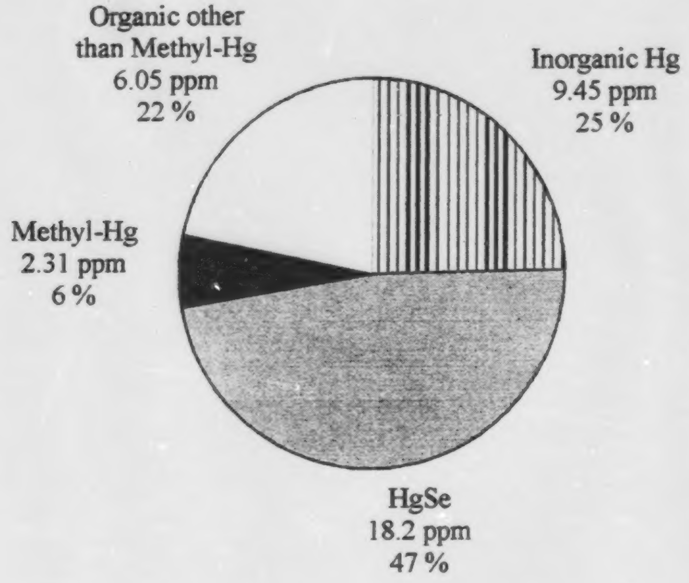

Figure 3. Pie chart showing arithmetic mean percentages of mercury 'species' in beluga liver.

at higher levels. Consequently, the conversion of methylmercury to other less toxic forms may be an adaptation that allows the whales to survive in spite of their high body burdens of mercury. Microscopic examination of whale samples will offer more detailed insight into the question of the meaning of these mercury levels and species to the whales.

The question whether a similar mechanism operates in other species including arctic people remains open.

Expected Project Completion Date: The speciation work with whale samples is complete. The effect studies are underway and will be available shortly.

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RADIATION EXPOSURE IN LUTSEL K'E

Project Leader: Chair of the Lutsel K'e Environment Committee

Project Team: Lutsel K'e Environment Committee; Lands and Environment, Dene Nation; David Kennedy, Contaminants Division, Department of Indian Affairs and Northern Development (DIAND); Laurie Chan, Centre for Indigenous Peoples' Nutrition and Environment (CINE); Colin Macdonald, Northern Environmental Consulting

OBJECTIVES

The goals of this project are to complete sample collection and analysis of radiation in the Lutsel K'e environment, to investigate the influence of local contaminated sites and to conduct a detailed radiation exposure assessment in the community.

Specific Objectives are:

1. To complete the environmental survey of terrestrial radiation and radionuclides in the Lutsel K'e environment.
2. To conduct a detailed exposure assessment for radiation in the community.
3, To analyse uranium, arsenic, radium and other metals in fish and mammals from the area of the Stark Lake mine site and other areas of elevated gamma radiation for evidence of contamination from the point sources.
4. To translate the results of the first and second year of sampling into the Chipewayan language for dissemination within Lutsel K'e and surrounding communities.

DESCRIPTION

Although organochlorines and metals were the primary focus of Phase I of the Northern Contaminants Program (NCP), radionuclides remain a major concern in some communities. In Lutsel K'e, these concerns have focussed on past exposures to radiation from atmospheric testing of nuclear weapons and debris from Cosmos 954 but also the abandoned Stark Lake mine which is adjacent to traditional fishing areas. An analysis of the diet of Dene communities by CINE has also shown slightly elevated radiation doses from the diet because of natural background radiation in caribou, the major traditional/country food (Berti *et al.* 1998). These past events and current exposures have led to a perception in the community that heightened exposure to radiation has led to increased cancers rates.

A program was initiated in 1997/98 to address the concerns of the community by measuring radiation within the immediate Lutsel K'e environment. Data from the Geological Survey of Canada show areas of increased background gamma radiation from uranium deposits in the area. This was supported by random gamma checks in 1997 which showed normal background gamma rates within the community but elevated levels at some sites (up to 2 $mGy{\cdot}y^{-1}$), probably due to uranium in the rocks. The study also showed elevated radon levels in one building (24 mWL) which exceed the U.S. guidelines for radiation exposure. These results show that there are point sources of radiation in the environment which may result in localised areas of high background gamma radiation and releases of radionuclides which are taken up by plants and animals. The examples of elevated environmental radiation are in addition to the higher levels in the diet caused by consumption of caribou. These results from the 1997/98 study show that radiation may be elevated in the area and that more detailed assessment is required.

The objective of the 1998/99 study is to collect more data on the natural background radiation in the community to improve the precision of assessments of exposure in these elevated areas. The study will examine the extent of higher background in the community, hunting camps and near the Stark Lake mine. Fish, mammals and birds near the mine site and local radiation sources will be analysed for radionuclides and metals, such as uranium, thorium and arsenic, which may be released from these point sources. The data will be used to construct a detailed assessment of radiation exposure of residents of Lutsel K'e.

ACTIVITIES IN 1998/99

Sampling was continued in 1998/99 to increase the number of samples of food items analysed and to assess the potential for radionuclide contamination entering the food web from the Stark Lake mine site. Samples of water, sediment and background radiation were measured at the Stark Lake site in July, 1998 (Table 1). Water was collected from a stream which discharges into Regina Bay of Great Slave Lake and sediment samples were collected near the discharge area of the stream.

Background radiation at waist height was measured in the community in May, 1998 and at the Stark Lake mine site in July, 1998 with a Ludlum 19 gamma meter. All measurements were taken at waist height except for specific point sources on the mine site. The meter was calibrated electronically in the lower ranges, however the higher ranges have been calibrated with ^{241}Am and hence the meter measures too high for uranium sources by about 67% for gamma rates above 500 µrad·h^{-1} (i.e., when the Ludlum 19 measures 5000 µrad·h^{-1} for a uranium source of an equivalent of about 3000 µrad·h^{-1}). For dose estimates to people, 1 µrad·h^{-1} as measured by the meter (dose in air) corresponds to a dose in a person's body from uranium on the ground of 0.006 µSv·h^{-1}.

Water samples were collected in a stream running down the hill near the mine site and at three locations in Great Slave Lake adjacent to the stream discharge. Water was collected in the stream about half-way down the hill (Sample 1) and about 20 m upstream of the discharge into the lake (Sample 2). Two samples of 500 mL each were collected and acidified with 50% nitric acid. Samples were not filtered. The samples were divided in two (250 mL each) and transported to Envirotest in Winnipeg for analysis of all metals by ICP/MS and for mercury, arsenic and antimony by hydride process. Water was digested with nitric acid following USEPA SW 846 method 3015 to give total metal concentrations. Arsenic was analysed by continuous hydride by flameless atomic absorption spectrometry following USEPA SW 846; APHA 3114C. Mercury was analysed by continuous cold vapour atomic absorption spectrometry following USEPA SW 846; APHA 3112B. Other metals were analysed by ICP/MS following USEPA method No. 200.8. Envirotest is accredited with the Standards Council of Canada in cooperation with the Canadian Association for Environmental Analytical Laboratories (CAEAL), the American Industrial Hygiene Association (AIHA), and Agriculture Canada. Sediments were collected by Eckman grab at four locations in the bay adjacent to the stream discharge. The top 2-3 cm were removed from the samples with a plastic scoop and stored in Whirlpak bags for analysis of radionuclides and metals.

RESULTS AND DISCUSSION

Background radiation levels in the community and at the Stark Lake mine site are shown in Figure 1 and Table 2. Background readings in the community are in the range of 10-19 µrad·h^{-1}, with a small area outside the community reaching 30 µrad·h^{-1}. The elevated level probably indicates a small deposit of uranium-rich rock. At the mine site, gamma readings increased from 10-15 µrad·h^{-1} on the beach and near the top of the hill to about 28-29 µrad·h^{-1} in a clearing at the top of the hill, south of the mine site. This range of dose is about the same as the range measured in Lutsel K'e during a survey in May, 1998 (Figure 1).

Much higher doses were recorded on the mine site. The values shown in Figure 1 are as observed and not corrected for the calibration error. Dose in air at the mine adit was about 100 µrad·h^{-1} however levels of about 900 µrad·h^{-1} were observed in a small shack adjacent to the adit. Levels ranging from 160-400 µrad·h^{-1} and 150-360 µrad·h^{-1} were observed along the tops of two waste rock piles, respectively, extending to the southwest. Each of these tailings piles extended about 40 m from the central GPS point, which was about 30 m from the mine adit. One point source of ore was identified at the base of the tailings pile with a dose rate of about 4000 µrad·h^{-1} on contact.

Raw data for the metal concentrations in water samples are summarised as means with standard deviations in Table 3. Silver, beryllium, bismuth, cadmium, mercury, antimony, tin, and thallium were below detection limits in all samples. The concentration of most other metals was higher in the stream water than in the lake water. Water hardness, estimated as the total of the calcium and magnesium ions, decreased from 80-90 mg·L^{-1} in the stream to less than 10 mg·L^{-1} in the lake samples.

Most metals were below detection limits in the stream and lake, or did not exceed any of the Environment Canada or Health Canada Water Quality Guidelines (Figure 2). Four of the mean metal concentrations exceeded one of the guidelines in at least one of the stream locations (Figure 2). Aluminum exceeded the aquatic protection guideline by almost 20 times while copper exceeded its guideline by about 10%. Iron exceeded both the drinking water standard and aquatic protection guidelines of 0.3 mg·L^{-1}. There is no guideline for strontium but it is shown in Figure 2 because of the much higher level in the stream relative to the lake. Uranium exceeds the new drinking water standard of 0.01 mg·L^{-1} by about 30 times in both stream samples. These levels suggest that there is a source of the metals (including uranium) which results in levels of the metals much higher than is considered background. This source could be from the uranium-rich rocks in the area or the

Table 1. Samples collected at Stark Lake mine and surrounding area.

Sample	Date	Location North	Location West	Comment
Water				
Stream Sample 1	July 30, 1998	NR	NR	mid-way from mine to lake
Stream Sample 2	July 30, 1998	62°26' 29.5" N	110°18' 49.6" W	20 m upstream from discharge to lake
Lake water sample 1	July 30, 1998	NR	NR	100 m offshore from stream discharge
Lake water sample 2	July 30, 1998	NR	NR	400 m west of Lake Water 1
Lake water sample 3	July 30, 1998	62°26' 21.2" N	110°18' 49.4" W	300 m south of Lake Water 1
Sediment				
Sample 1	July 30, 1998	NR	NR	100 m offshore from stream; depth of 3 m
Sample 2	July 30, 1998	62°26' 27.4" N	110°18' 58.4" W	220 m offshore; 300 m west from stream discharge; depth of 7 m
Sample 3	July 30, 1998	62°26' 25.1" N	110°18' 47.5" W	400 m south of stream discharge; 200 m offshore

NR - no reading

Table 2. Measured dose rates at Stark Lake mine site using Ludlum 19 rate meter.

Site	Date	Location North	Location West	Uncorrected Dose in Air	Comment
Beach	July 30, 1998	62°26' 29.5" N	110°18' 49.6" W	10 - 15	0.7 km from mine adit
Mid-way to mine site from beach	July 30, 1998	62°26' 32.2" N	110°18' 31.1" W	10 - 15	0.4 km to mine adit
Near mine site	July 30, 1998	NR	NR	28-29	0.3 km south of site
Mine Site	July 30, 1998	62°26' 49.3"N	110°18' 27.9" W	160	30 - 40 m from mine adit
Shack near adit	July 30, 1998	NR	NR	900	10 m from adit
Mine Adit	July 30, 1998	62°26 44.7" N	110°18' 31.8" W	100	
Point source ore sample	July 30, 1998	NR	NR	4000	bottom of tailings pile

NR - no reading

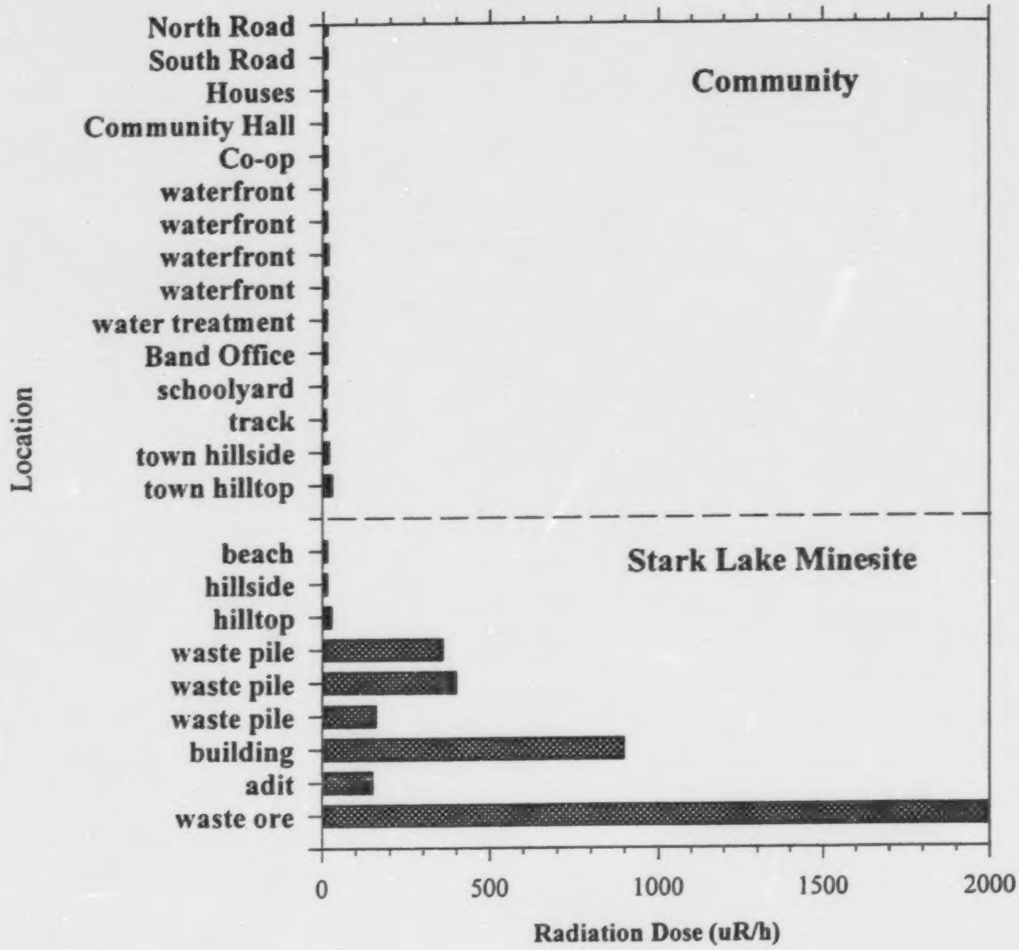

Figure 1. Background gamma dose in air at waist height in the community of Lutsel K'e and at the Stark Lake mine site. July, 1998.

crushed rock from the mine site. It is not possible to tell from this project what the source of contamination is, and to determine the source would require more intensive sampling.

The concentrations of metals in the four sediment samples are given in Table 4. All sediments are characterised by very high levels of aluminum and iron. There is no major difference in the concentrations of metals in the four locations, which ranged from 100 m from the stream discharge point to about 0.5 km south of that area. The major exception to this is the level of uranium which is 69 mg·kg^{-1} dry weight near the discharge point and below detection limit in all other sites.

Fish were collected near the mine site and the levels of radionuclides were not significantly different than fish collected in Stark Lake proper and Great Slave Lake in 1997/98. These food data (Table 5) were combined to provide data for an assessment of the daily and annual exposure to radiation through their diet (Table 6). The analysis was conducted by Dr. Laurie Chan, CINE using data on the specific amounts of food items consumed in the community. In general, there is no evidence of higher levels of radionuclides in the food items due to the Stark Lake mine. The daily intake of radionuclides results in a dose of approximately 0.004 mSv, giving a total annual dose of 1.29 mSv. However, if the input from ^{40}K is removed from the analysis because the level of this nuclide is highly regulated by the body and the amount in the diet does not give an additional dose, then the dose decreases to close to 1 mSv·y^{-1}. This exposure is slightly higher than the average levels in

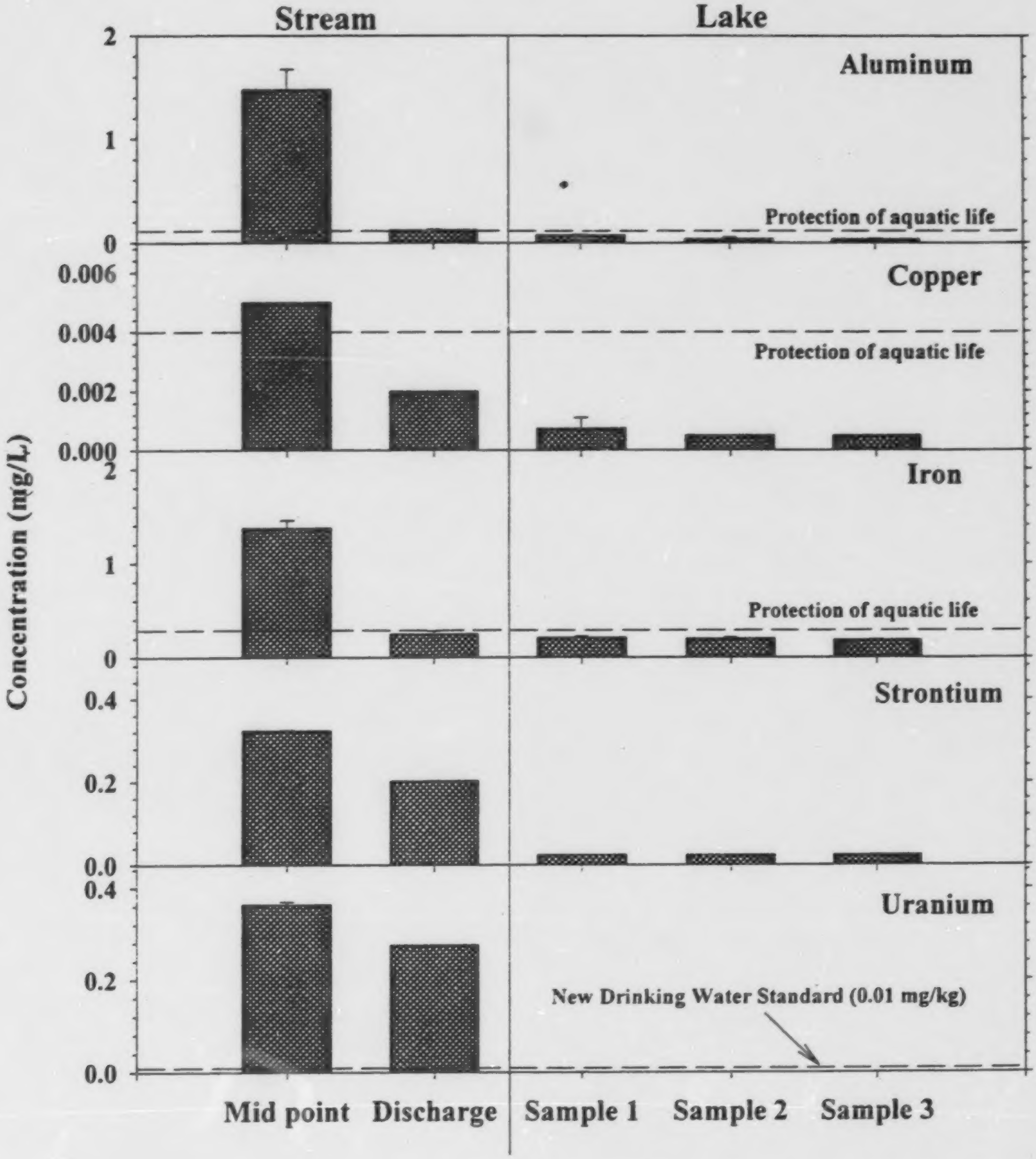

Figure 2. Concentration of metals in the stream near the Stark Lake mine site relative to water collected in Regina Bay (Great Slave Lake) near the stream discharge point. The higher concentrations in the stream indicate a local source of uranium and other matels, although it is not known if the source is natural (i.e. the original uranium deposit) or from the waste ore on the mine site.

Table 3. Mean total metal concentrations and standard deviations (SD) for stream and lake water samples at the Stark Lake mine site. All concentrations are in mg·L^{-1}. The following metallic elements were at or below detection limits in all samples: arsenic (DL = 0.001 mg·L^{-1}), bismuth (DL = 0.0001 mg·L^{-1}), beryllium (DL = 0.001 mg·L^{-1}), cadmium (DL = 0.0002 mg·L^{-1}), mercury (DL = 0.0002 mg·L^{-1}), antimony (DL = 0.0008 mg·L^{-1}), tin (DL = 0.0004 mg·L^{-1}), thallium (DL = 0.0001 mg·L^{-1}).

Element	Symbol	STREAM				LAKE					
		Mid point		Discharge		Sample 1		Sample 2		Sample 3	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Silver	Ag	<0.0004		<0.0004		<0.0004		0.0004	0.0003	<0.0004	
Aluminum	Al	1.480	0.198	0.1250	0.0071	0.0750	0.0071	0.0400	0.0141	0.0350	0.0071
Arsenic	As	0.001	0	<0.001		<0.001		<0.001		<0.001	
Barium	Ba	0.089	0.002	0.0776	0.0009	0.0093	0.0001	0.0092	0.0004	0.0091	0.0002
Boron	Bo	0.134	0.002	0.0940	0.0028	0.0075	0.0021	0.0070	0.0014	0.0047	0.0024
Calcium	Ca	51.10	0.57	55.50	0.14	5.05	0.21	4.95	0.07	4.85	0.07
Cobalt	Co	0.001	0	<0.0002		<0.0002		<0.0002		<0.0002	
Chromium	Cr	0.003	0	0.0008	0.0006	0.0008	0.0005	0.0006	0.0005	<0.0008	
Copper	Cu	0.005	0	0.0020	0	0.0008	0.0004	<0.001		<0.001	
Iron	Fe	1.38	0.08	0.25	0.03	0.21	0.01	0.20	0.01	0.18	0.01
Potassium	K	5.05	0.06	3.43	0.01	0.68	0.04	0.70	0.05	0.72	0.01
Magnesium	Mg	27.20	0.57	26.15	0.21	1.60	0.08	1.60	0.04	1.62	0.04
Manganese	Mn	0.0340	0.0013	0.0015	0.0001	0.0014	0.0001	0.0012	0	0.0014	0.0001
Molybdenum	Mo	0.0088	0.0002	0.0051	0.0001	0.0002	0.0001	0.0003	0.0001	0.0002	0.0000
Sodium	Na	10.35	0.21	11.6500	0.0707	1.50	0	1.45	0.07	1.50	0
Nickel	Ni	0.002	0.001	0.0002	0.0002	0.0008	0.0002	0.0006	0	0.0008	0.0004
Phosphorus	P	0.085	0.007	0.0450	0.0071	0.0400	0	0.0350	0.0071	0.0300	0
Lead	Pb	0.001	0.0002	0.0001	0.00004	<0.0001		<0.0001		<0.0001	
Selenium	Se	0.002	0.0001	0.0006	0.0003	<0.0008		<0.0008		<0.0008	
Strontium	Sr	0.324	0.001	0.202	0.001	0.024	0.00049	0.024	0.00014	0.024	0.001
Titanium	Ti	0.062	0.004	0.006	0.002	0.002	0.00028	0.001	0.00007	0.001	0.00021
Uranium	U	0.364	0.005	0.2760	0	0.0006	0.0004	0.0002	0	0.0001	0.00004
Vanadium	V	0.004	0.0001	0.0008	0.0001	0.0006	0	0.0004	0.0001	0.0004	0
Zinc	Zn	0.014	0.010	<0.0004		0.0045	0.0035	<0.0004		0.0050	0.0014

Table 4. Concentration of metals in sediments collected near the Stark Lake minesite. All concentrations are in mg·kg^{-1} DW. Silver (DL = 1 mg·kg^{-1}), beryllium (DL = 1 mg·kg^{-1}), cadmium (DL = 0.5 mg·kg^{-1}), molybdenum (DL = 1 mg·kg^{-1}), tin (DL = 5 mg·kg^{-1}) and thallium (DL = 1 mg·kg^{-1}) were below detection in all samples.

Metal		Sediment 1	Sediment 2	Sediment 3	Sediment 4	Average	Standard Deviation
Aluminum	Al	8490	10700	11800	10500	10373	1379
Arsenic	Ar	3	4.9	3.9	3.3	3.8	0.84
Barium	Ba	112	118	130	109	117.3	9.29
Boron	Bo	10	13	11	8	10.5	2.08
Calcium	Ca	4610	4180	4520	3550	4215	480
Cobalt	Co	9	10	10	8	9.3	0.96
Chromium	Cr	22.6	26.7	32.8	26.7	27.2	4.20
Copper	Cu	18	16	17	16	16.8	0.96
Iron	Fe	18800	26600	20500	16600	20625	4291
Mercury	Hg	0.04	0.04	0.03	0.02	0.03	0.01
Potassium	K	2050	2620	2850	2290	2452	353
Magnesium	Mg	4830	4880	6030	5070	5202	561
Manganese	Mn	434	666	512	269	470	165
Sodium	Na	172	202	246	215	209	31
Nickel	Ni	17	18	23	19	19.3	2.63
Lead	Pb	13	12	13	8	11.5	2.38
Selenium	Se	0.7	0.6	0.3	0.7	0.58	0.19
Strontium	Sr	35	46	62	44	46.8	11
Titanium	Ti	383	526	729	652	573	152
Uranium	U	69	<40	<40	<40	<40	
Vanadium	V	22	28	33	30	28.3	4.65
Zinc	Zn	47	47.9	52.2	43.6	47.7	3.54

Table 5. Concentration of radionuclides in food items in the area around Lutsel K'e, NWT. Fish were collected in Great Slave Lake, Stark Lake and Regina Bay, adjacent to the Stark Lake mine site. Reported values are averages with standard deviations.

Species	Sample	n	Collection Date	% Dry Wt.	% Ash Wt.	^{40}K (Bq·kg^{-1})	^{137}Cs (Bq·kg^{-1})	^{210}Pb (Bq·kg^{-1})	^{226}Ra (Bq·kg^{-1})	^{232}Th (Bq·kg^{-1})	^{210}Po (Bq·kg^{-1})
caribou	meat	2	Nov., 1997	24.1 (1.0)	n/a	180 (5.0)	143 (9.9)	<2	<0.2	<1.0	12.3 (2.3)
	kidney	3	Nov/Dec., 1997	20.3 (1.3)	n/a	139 (23.1)	276 (67.6)	65.6 (38.5)	< 0.20	< 1.0	187 (87.8)
	liver	5	Dec. 20, 1997	31.1 (1.3)	1.11 (0.52)	136 (36.5)	115 (59.0)	87.0 (37.1)	< 0.20	< 1.0	270 (67.4)
	stomach	1	Nov. 1, 1997	23.70	n/a	198	159	< 2.0	< 0.20	< 1.0	34.3
rabbit	meat	1	Dec. 15, 1997	24.7	0.79	103	12.4	< 1.4	< 0.24	< 0.34	0.84
moose	meat	1	Dec. 15, 1997	25.3	0.59	99.4	2.21	< 0.65	0.09	< 0.13	0.50
loche	liver	7	Dec. 18, 1997	35.9 (4.22)	0.97 (0.21)	116 (13.9)	1.72 (0.87)	< 5	< 0.54	< 1.2	4.05 (3.01)
whitefish	flesh	6	Dec. 1997 / Jul. 1999	22.6 (2.07)	0.86 (0.39)	141 (60.5)	4.77 (1.49)	< 2.6	< 1.30	<0.6	0.11 (0.05)
lake trout	flesh	3	Dec., 1997	21.9 (0.55)	0.64 (0.23)	107 (27.9)	3.29 (1.43)	< 1.0	< 0.17	< 0.2	< 0.3
white sucker	flesh	1	Dec. 11, 1997	18.2	0.77	141	2.28	< 0.81	< 0.12	< 0.16	< 0.01
northern pike	flesh	5	Dec. 1997 / Jul. 1999	21.1 (0.77)	0.94 (0.37)	121 (2.83)	3.94 (1.64)	<2.6	<0.4	<0.6	0.23 (0.25)
cranberries	whole	1	Dec. 15, 1997	17.51	0.10	26.21	2.09	< 1.7	0.30	< 0.46	0.52

na = not available

Table 6. Estimate of exposure to the Lutsel K'e Dene from radionuclides in their diet. Consumption of food items based on data from Berti *et al.* (1998).

Species	Food Type	Preparation	Number of Consumers	Amount Consumed (g)	^{40}K (Bq·g^{-1})	^{137}Cs (Bq·g^{-1})	^{210}Pb (Bq·g^{-1})	^{226}Ra (Bq·g^{-1})	^{232}Th (Bq·g^{-1})	^{210}Po (Bq·g^{-1})
caribou	meat	dried	17	6	5.96e-01	4.75e-01	3.32e-03	1.20e-02	1.66e-03	4.08e-02
caribou	meat	baked	95	100	2.41e-01	1.92e-01	1.34e-03	4.82e-03	6.70e-04	1.65e-02
caribou	kidney	baked	1	0.4	5.02e-04	4.00e-04	2.80e-06	1.20e-04	6.00e-04	3.44e-05
caribou	liver	baked	1	0.7	1.63e-01	1.38e-01	1.04e-01	1.20e-04	6.00e-04	3.24e-01
caribou	stomach		0	.						
rabbit	meat	boiled	3	2	1.03e-01	1.24e-02	1.00e-03	1.20e-04	1.70e-04	8.35e-04
moose	meat	dried	11	2	3.30e-01	7.33e-03	9.96e-04	2.95e-04	1.99e-04	1.65e-03
moose	meat	baked	53	54	1.33e-01	2.96e-03	4.02e-04	1.19e-04	8.04e-05	6.66e-04
loche	liver		0	.						
whitefish	flesh	baked	23	21	1.64e-01	5.54e-03	1.51e-03	7.54e-04	3.48e-04	1.32e-04
lake trout	flesh	baked	7	5	1.24e-01	3.82e-03	5.80e-04	9.28e-05	1.16e-04	1.74e-04
white sucker	flesh		2	1.5	1.64e-01	2.65e-03	4.64e-04	6.96e-05	9.28e-05	5.80e-06
northern pike	flesh		0	.						
cranberries	whole		1	1	2.62e-02	2.09e-03	8.50e-04	3.02e-04	2.30e-04	5.19e-04
	TOTAL		**214**	**193.6**	**40.14**	**22.4**	**0.29**	**0.58**	**0.09**	**2.17**
Dose Conversion Factors (mSv·Bq^{-1})					6.20e-06	1.30e-05	7.00e-04	2.80e-04	2.20e-04	1.20e-03
Exposure (mSv·day^{-1})					2.49e-04	2.92e-04	2.02e-04	1.62e-04	2.00e-05	2.60e-03

Total Exposure (mSv·d^{-1}) 0.004
Total Exposure (mSv·y^{-1}) 1.29

southern diets, however most of the dose comes from naturally-occurring radionuclides in caribou and the higher dose is more than balanced by the cultural and social benefits of hunting and consuming caribou. There is no evidence that the radiation which is present on the Stark Lake site increases the dose to people in the Lutsel K'e area.

CONCLUSIONS

There is no evidence of remaining radioactive debris from Cosmos 954 that would result in continuing exposure of people in Lutsel K'e to elevated levels of radiation.

High levels of radon gas were observed in the Lutsel K'e Community Hall in 1997/98 which should be monitored and rectified by change in the building if necessary.

Exposure to radiation through the traditional diet in Lutsel K'e, based on dietary studies and field surveys of radionuclides in food items, is estimated at 1.29 $mSv \cdot y^{-1}$. Naturally occurring radionuclides in caribou provide the major portion of radiation exposure, however, the social, cultural and health benefits from hunting and consuming caribou probably far outweigh the risk from the slightly elevated levels.

Elevated levels of radiation are evident on the Stark Lake mine site from waste ore and crushed rock. Doses in the air at waist height are 20-30 times higher than background doses in the community, although the area with elevated levels is relatively small. Samples of water and sediment at a stream discharge site show levels of uranium and other metals exceeding Canadian Water Quality Guidelines for Drinking Water and the Protection of Aquatic Life. It is not clear if the high levels in water are due to the waste rock on the mine site or due to deposits of uranium contaminating ground water.

Although measurements indicate that radiation exposure is slightly elevated in Lutsel K'e from the diet and radon exposure, there is little indication that the radiation on the Stark Lake site significantly increases the dose to people in the Lutsel K'e area because the people spend relatively little time on the mine site and radionuclides levels in fish are not different from those in Great Slave Lake. However, high radiation levels are present on the site and radionuclides are present in a nearby stream which may indicate that materials may be moving off-site. Further work would define the source of the contamination and the amount of materials moving into adjacent water of Great Slave Lake.

Project Completion Date: March, 1999

REFERENCES

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SPATIAL TRENDS AND PATHWAYS OF POPS AND METALS IN FISH, SHELLFISH AND MARINE MAMMALS OF NORTHERN LABRADOR AND NUNAVIK

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OBJECTIVES

1. To determine spatial and temporal trends of persistent organic pollutants (POPs) and metals in freshwater and anadromous fish, shellfish, and marine mammals that are important sources of nutrition to Inuit communities of Northern Labrador, Nunavik and Nunavut, for use in human health risk assessment and to contribute to discussion on the effectiveness of international actions to control POPs; and
2. To develop baseline data on contaminants in marine biota in Labrador for comparison with other Canadian Arctic regions.

DESCRIPTION

The Nunavik/Labrador Action Plan meeting (May 1997) recommended that a comprehensive contaminants monitoring program should be developed in Nunavik and Labrador, with a special emphasis on studies in Labrador. This meeting was attended by community representatives from Labrador and Nunavik, as well as by representatives of various agencies dealing with contaminant and human health issues in the North. The proceedings of the workshop were circulated to attendees in the Fall of 1997 (Muir 1997).

The assessment of spatial and temporal trends of contaminants conducted by the Northern Contaminants Program (NCP; Jensen *et al.* 1997, Muir *et al.* 1997) found that, with the exception of waterfowl and gamebirds, there was no information on contaminants in biota important to the communities of Northern Labrador. There were information gaps pertaining to contaminants in Nunavik and Nunavut, especially for anadromous and freshwater fishes and for mussels, which were all identified as very important to the communities at the Nunavik/Labrador Action Plan meeting.

Beginning in Fall 1997, the analyses of samples of ringed seal, char and blue mussel from Labrador began with the help of archived seal and char samples provided by the Department of Fisheries and Oceans (DFO). The preliminary results, reported in a previous NCP Synopsis report (Muir *et al.* 1999), showed that heavy metals and organochlorines in ringed seal tissues and in char muscle from Labrador were similar to levels in samples from Nunavik. Arsenic was the most prominent toxic element found in mussels (1.5-2.2 $\mu g \cdot g^{-1}$ wet wt). Sample sizes for all biota were limited because of the preliminary nature of the study (start-up in late October 1997). Butyltins were detected in all samples from Labrador, although at relatively low levels compared to other reports for marine biota near harbours. Dibutyltin (DBT) was the most prominent butyltin, possibly reflecting degradation of tributyltin (TBT). Concentrations of butyltins in seal blubber were at the low end of the range reported for sea lion livers from the coast of Japan (Kim *et al.* 1996); there are no previous reports for ringed seal tissues.

This report describes results for samples collected in 1998. Collections were conducted by hunters and fishers from each participating community and coordinated in Labrador by the Labrador Inuit Association (LIA) and in Nunavik by the Nunavik Research Centre (NvRC).

ACTIVITIES IN 1998/99

Sample collection

Successful collection of ringed seal samples were made at two locations in Labrador (Nain and Makkovik) and at five locations in Nunavik near communities in the Ungava and Hudson Strait area (Kangiqsualujjuaq (George River), Kuujjuaq, Kangiqsujuaq (Wakeham), Kangiqsuk, and Salluit) in Spring 1998. Hunters obtained samples of blubber, brain/cerebrum, kidney, muscle and liver plus the lower jaw for tooth aging, using a kit provided by NvRC. Blue mussels (*Mytilus edulis*) were successfully collected by the LIA at three locations in Labrador (Nain, Hopedale and Makkovik) and at three locations in Nunavik. Arctic char (*Salvelinus alpinus*) samples were obtained in two Labrador communities and five locations in Nunavik. At the request of the community, landlocked char from a lake near Kangiqsujuaq were also included. All samples were shipped to the NvRC for subsampling and distribution to the analytical labs. Biological measurements on the seals and fish (e.g. age, size, sex) were made at NvRC.

Chemical analysis

Samples were analysed for heavy metals (cadmium, mercury, lead, selenium and arsenic) at NvRC (Kuujjuaq) in M. Kwan's lab using atomic absorption spectrophotometry. Analysis for butyltins was conducted by electrospray ionization tandem mass spectrometry or MS/MS at DFO (St. John's) in J. Banoub's lab. Persistent organic pollutants (e.g. PCBs, DDT, etc.) were determined in seal, char and mussels at the National Water Research Institute (NWRI) by the National Laboratory for Environmental Testing (NLET).

PCBs and other organochlorines were analysed by gas chromatography with electron-capture detection (GC-ECD). In brief, fish and mussel samples were homogenized and Soxhlet extracted with dichloromethane:hexane (1:1). Organochlorines were isolated by gel permeation chromatography (GPC) followed by silica gel cleanup then analysed by GC-ECD. Separation was accomplished on an HP 6890 GC using a 30m DB-5 column with H_2 carrier gas. ΣPCBs represented the sum of 103 congeners (see listing in Table 3 footnote). Toxaphene was analysed by low resolution GC-negative ion MS using an HP 5973 MSD in negative ion mode.

Coplanar PCBs were determined by M. Lebeuf's lab at Institut Maurice Lamontagne (IML) on subsamples of ringed seal blubber extracts (lipid removed by GPC) provided by NLET. Extracts were spiked with ^{13}C-non-*ortho* PCB surrogates by NWRI and shipped to IML where they were subjected to chromatography on carbon columns to isolate planar PCBs prior to GC-MS/MS (ion trap) analysis for coplanar PCBs (77,126,169). Mono-*ortho* PCBs (105,114,118,156) were analysed by NLET using GC-ECD.

Quality assurance steps included the analysis of reference materials for heavy metals and organochlorines, reagent blanks and duplicate samples. The NvRC and NLET organics lab are participants in the NCP Quality Assurance Program and in QUASIMEME programs for heavy metals and PCBs, respectively. The NLET is certified by the Canadian Environmental Analytical Laboratory program of the Canadian Standards Association.

RESULTS

Heavy metals

Low concentrations of mercury, selenium and arsenic were found in the 92 char samples analysed from two locations in Labrador and five locations in Nunavik (Table 1). We had previously reported undetectable levels of cadmium and lead in char muscle (<0.001-<0.006 $\mu g \cdot g^{-1}$ wet weight (wt.)) and these metals were again near, or at detection limits and are not included in Table 1. Arsenic was the most prominent of the five metals. Highest average levels (1.02 $\mu g \cdot g^{-1}$ wet wt.) were found in char from Povungnituk (eastern Hudson Bay) and lowest levels in samples from Nain. There has been little previous work on arsenic in fishes from northern Quebec or Labrador. Six char muscle samples from the Nain area analysed in 1997/98 had similar mean levels (0.19 $\mu g \cdot g^{-1}$ wet wt.) to the larger set analysed in this study (Muir *et al.* 1999). Average mercury levels in sea-run char were similar in all samples from sites in Labrador and Nunavik, ranging from means of 0.032 to 0.072 $\mu g \cdot g^{-1}$ wet wt. Similar levels were reported for a small set of char samples from Nain in 1997 (Muir *et al.* 1999) and from eastern Hudson Bay communities in 1994 (Muir *et al.* 1997). About three-fold higher levels of mercury were found in landlocked char from Kangiqsujuaq than sea run char. However, selenium, which may exert a protective effect for mercury exposure, was also much higher in the landlocked animals.

Three to five types of tissues from 73 ringed seals from two locations in Labrador and five locations in Nunavik were analysed for mercury, selenium, cadmium and arsenic (Table 2). In general, mean concentrations of each element were similar in Labrador and Nunavik samples although slightly higher levels of mercury were found in seal muscle samples from Labrador. Brain/cerebrum samples had the lowest levels of metals. Muscle samples had relatively low levels ranging from means of 0.19 $\mu g \cdot g^{-1}$ wet wt. in Salluit to 0.46 $\mu g \cdot g^{-1}$ wet wt. at Makkovik. Further statistical analysis, taking into account age of the animals, is needed to determine if mercury is significantly higher in the Labrador muscle samples. Ringed seal liver contained relatively high concentrations of mercury at all 7 locations (Table 2). The range of average mercury concentrations (4.95-20.3 $\mu g \cdot g^{-1}$ wet wt.) was similar to previous observations for eastern Arctic ringed seals (Muir *et al.* 1997). For example, mercury in ringed seal liver from the eastern Arctic (including Northern Quebec, Resolute, Arctic Bay) averaged 8.3±7.0 $\mu g \cdot g^{-1}$ wet wt. (Wagemann 1995). Cadmium concentrations were also relatively high in

Table 1. Average concentrations (µg·g^{-1} wet wt. ± SD) of mercury, selenium and arsenic in sea-run arctic char muscle from Northern Quebec and Labrador, 1998.

Location	N	age yrs	weight kg	Mercury µg·g^{-1} wet wt.	Selenium µg·g^{-1} wet wt.	Arsenic µg·g^{-1} wet wt.
LABRADOR						
Hopedale	13	7 ± 1	1.78 ± 0.40	0.033 ± 0.005	– –	– –
Nain	14	8 ± 1	1.44 ± 0.30	0.035 ± 0.011	– –	0.211 ± 0.064
NORTHERN QUÉBEC						
Kangiqsuk	15	8 ± 1	1.70 ± 1.98	0.032 ± 0.026	0.235 ± 0.069	0.256 ± 0.062
Tasuijaq	15	9 ± 2	1.35 ± 0.40	0.040 ± 0.011	0.144 ± 0.023	0.414 ± 0.147
Quaqtaq	14	9 ± 2	1.30 ± 0.58	0.072 ± 0.035	– –	– –
Povungnituk	11	8 ± 1	1.47 ± 0.43	0.044 ± 0.009	– –	1.015 ± 0.182
Kangiqusujuak (landlocked)	8	12 ± 2	1.41 ± 0.26	0.131 ± 0.050	0.600 ± 0.211	– –
Kangiksujuak (sea-run)	2	12	1.73 –	0.037 –	0.26 –	– –

Table 2. Concentrations of heavy metals (µg·g^{-1} wet wt.) in tissues of ringed seal from Labrador and Northern Quebec (1998)[1]

Location	Tissue	N	age (yrs)	Mercury µg·g^{-1} wet wt.	Selenium µg·g^{-1} wet wt.	Cadmium µg·g^{-1} wet wt.	Arsenic µg·g^{-1} wet wt.
LABRADOR							
Makkovik	brain	9	5 ± 3	0.13 ± 0.07	0.30 ± 0.08	0.01 ± 0.01	– –
	cerebrum	6	7 ± 2	0.19 ± 0.12	0.34 ± 0.06	0.01 ± 0.00	– –
	kidney	14	6 ± 2	1.19 ± 0.50	2.06 ± 0.37	6.75 ± 2.59	0.025 ± 0.033
	liver	14	6 ± 2	10.4 ± 5.24	7.52 ± 2.59	3.29 ± 2.30	0.024 ± 0.020
	muscle	14	6 ± 2	0.46 ± 0.24	0.38 ± 0.09	0.01 ± 0.01	– –
Nain	cerebrum	15	6 ± 3	0.09 ± 0.04	0.30 ± 0.06	0.02 ± 0.02	– –
	kidney	13	6 ± 2	1.03 ± 0.30	2.47 ± 0.45	8.69 ± 6.47	0.016 ± 0.008
	liver	13	6 ± 2	7.25 ± 4.65	6.06 ± 2.26	3.66 ± 2.57	0.020 ± 0.014
	muscle	13	6 ± 2	0.31 ± 0.15	0.49 ± 0.08	0.04 ± 0.06	0.022 ± 0.012
NORTHERN QUEBEC							
Kangisualujjuaq							
	cerebrum	5	7 ± 3	0.09 ± 0.02	0.23 ± 0.01	0.03 ± 0.03	– –
	kidney	9	7 ± 4	0.86 ± 0.23	– –	– –	– –
	liver	9	7 ± 4	9.17 ± 10.3	6.96 4.60	3.48 ± 1.94	– –
	muscle	9	7 ± 4	0.26 ± 0.12	– –	– –	– –
Kangirsuk	cerebrum	2	3–	0.07	0.27	0.01	– –
	kidney	4	3 ± 3	1.58 ± 1.14	– –	– –	– –
	liver	4	3 ± 3	20.3 ± 33.5	10.2 ± 13.4	8.81 ± 6.20	– –
	muscle	4	3 ± 3	0.31 ± 0.12	– –	– –	– –
Kuujjuaq	cerebrum	6	2 ± 3	0.04 ± 0.02	0.23 ± 0.02	0.02 ± 0.00	– –
	kidney	7	2 ± 2	0.78 ± 0.44	1.63 ± 0.36	7.19 ± 7.92	– –
	muscle	2	2 –	0.23	– –	– –	– –
Quaqtaq	cerebrum	10	7 ± 3	0.09 ± 0.06	0.24 ± 0.03	0.02 ± 0.01	– –
	kidney	12	6 ± 4	0.93 ± 0.40	1.99 ± 0.50	8.81 ± 13.4	0.012 ± 0.006
	liver	12	6 ± 4	13.3 ± 14.5	9.06 ± 6.47	4.08 ± 4.58	0.017 ± 0.004
	muscle	12	7 ± 3	0.25 ± 0.18	0.40 ± 0.04	0.02 ± 0.03	– –
	whole brain	3	6 ± 4	0.07 ± 0.05	0.22 ± 0.01	0.03 ± 0.02	– –
Salluit	cerebrum	6	2 ± 4	0.22 ± 0.44	0.27 ± 0.05	0.01 ± 0.01	– –
	kidney	12	4 ± 5	0.64 ± 0.36	– –	– –	– –
	liver	12	4 ± 5	4.95 ± 7.28	4.07 ± 3.47	7.53 ± 5.13	– –
	muscle	10	5 ± 6	0.19 ± 0.09	– –	– –	– –
	whole brain	2	2	0.07	0.30	0.03	–

[1] Dash indicates sample not yet analysed for this element

Table 3. Concentrations of persistent organochlorine pesticides and PCBs (ng·g^{-1} wet wt.) in Arctic char muscle from Labrador and Northern Quebec[1].

Location	N	Lipid (%)	Di/triCBz	ΣCBz	ΣHCH	ΣCHL	Dieldrin /aldrin /endrin	ΣDDT	mirex	Mono/ di- PCB	Tri– PCB	Tetra– PCB	Penta– PCB	Hexa– PCB	Hepta– PCB	Octa– PCB	Nona/ Deca- PCB	ΣPCB
LABRADOR																		
Nain	3	7.7	0.44	1.40	3.37	1.40	1.00	1.52	0.01	0.66	1.05	2.21	3.25	4.75	2.10	0.45	<0.01	14.5
Hopedale	2	6.5	1.41	1.18	2.19	1.19	0.87	1.50	0.01	0.46	2.66	4.95	5.28	2.67	0.77	0.15	<0.01	16.9
NORTHERN QUEBEC																		
Kangirsuk	2	9.3	0.30	1.16	1.03	1.21	1.33	1.12	0.01	0.32	0.82	1.51	2.00	1.06	0.25	0.05	<0.01	6.0
Quaqtaq	2	10.3	0.42	1.52	1.17	1.44	0.96	1.38	0.02	0.13	0.68	1.58	2.36	1.74	0.49	0.11	0.02	7.1
Kangiqsujuak	3	8.1	0.30	1.63	0.73	1.72	1.27	1.79	0.03	0.16	0.69	1.42	2.22	1.53	0.46	0.09	<0.01	6.6

[1] Footnotes:

Di/triCBz = sum of 1,3-DCB, 1,4-DCB, 1,2-DCB, 1,3,5-TCB, 1,2,4-TCB, 1,2,3-TCB
ΣCBz = sum of 1234-tetra, penta- and hexachlorobenzene
ΣHCH = sum of α-HCH, β-HCH and γ-HCH (except in seal muscle & liver = sum of α–HCH and β-HCH)
ΣCHL = sum of heptachlor, heptachlor epoxide, γ–chlordane, α–chlordane, *trans*-nonachlor, *cis*-nonachlor
ΣDDT = sum *o,p'*-DDE, *o,p'*-DDD, *o,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, *p,p'*-DDT (except in seal liver and muscle = sum of *o,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, *p,p'*-DDT).
ΣPCB = sum of 86 PCB peaks (103 congeners)(1, 3, 4/10, 7/9, 6, 8/5, 19, 12/13, 18, 15/17, 24/27, 16/32, 54/29, 26, 25, 31/28, 50, 33, 20, 53, 51, 22, 45, 46, 52, 49, 43, 48/47, 44, 59, 42, 64/41/71, 40, 100, 63, 74, 70/76/98, 66, 95, 91, 55, 56/60, 92, 84, 101, 99, 119, 83, 97, 87/81, 85, 136, 110, 82, 151, 135/144, 147, 107, 149, 118, 133, 114, 134/131, 146, 153, 132, 105, 141, 179, 137, 176, 130, 138/163, 158, 129, 178, 175, 187/182, 183, 128, 167, 185, 174, 177, 202/171, 156, 173, 157/201, 172, 197, 180, 193, 191, 200, 170/190, 198, 199, 203/196, 189, 208/195, 207, 194, 205, 206, 209).

Table 4. Concentrations of persistent organochlorine pesticides and PCBs (ng·g^{-1} wet wt.) in ringed seal blubber, liver and muscle from Labrador and Northern Quebec[1].

Location	Sex	N	Age (yrs)	Lipid (%)	Di/triCBz	ΣCBz	ΣHCH	ΣCHL	Dieldrin /aldrin /endrin	ΣDDT	mirex	Mono/ di- PCB	Tri– PCB	Tetra– PCB	Penta– PCB	Hexa– PCB	Hepta– – PCB	Octa– PCB	Nona/ Deca- PCB	ΣPCB
BLUBBER																				
Labrador																				
Nain	F	4	6	85	7.8	7.4	84.5	76.5	21.6	133	1.7	2.2	21.2	41.3	109	280	169	39.5	1.3	663
	M	5	5	86	12.8	9.9	86.6	104	31.5	192	2.0	2.2	22.1	45.4	126	236	105	26.6	1.1	564
Makkovik	M	9	5	90	9.4	9.6	85.3	109	33.3	209	1.6	2.2	20.2	39.8	102	204	84.2	18.8	0.7	472
Northern Quebec																				
Quaqtaq	F	5	7	89	7.5	11.4	109	98.0	57.2	190	3.4	7.9	34.3	34.9	108	127	44.1	12.3	1.0	384
	M	4	4	83	8.1	12.9	147	193	68.1	500	2.9	3.6	51.3	67.6	226	240	58.4	12.8	0.7	660
Kuujjuaq	F	4	2	99	28.6	18.5	183	183	88.9	290	2.4	1.6	46.0	74.2	198	241	78.6	16.8	0.6	656
	M	3	3	97	29.3	26.9	218	274	75.3	670	4.2	2.3	66.3	109	319	368	90.7	22.9	1.3	980
Kangiqsua–lujjuaq																				
	F	5	7	100	18.3	14.5	132	133	45.3	224	7.0	3.9	34.4	49.7	106	180	74.1	25.6	3.3	476
	M	2	5	100	12.5	16.2	155	243	65.5	423	3.4	4.6	42.7	61.8	158	218	57.9	12.4	0.8	557
MUSCLE																				
Nain	F	5		5.3	10.3	0.3	1.8	0.6	5.2	1.4	0.02	1.7	5.7	19.0	22.0	10.7	6.1	1.4	0.35	67
	M	5		4.62	27.5	0.5	2.0	0.6	5.1	1.9	0.15	1.8	7.2	20.7	22.5	10.3	5.9	1.2	0.36	70
LIVER																				
Nain	F	5		4.86	54.4	1.0	2.4	2.9	13.5	1.1	<0.01	1.7	14.1	30.1	40.8	21.2	23.7	0.8	0.45	133
	M	5		5.62	48.6	1.2	2.3	2.2	10.4	1.8	<0.01	1.5	10.7	22.0	34.2	21.2	16.9	1.6	0.32	108

[1] For individual compounds in each Organochlorine group see Table 3.

Table 5. Concentrations of coplanar and mono–*ortho* PCBs in ringed seal blubber from Labrador and Northern Quebec[1].

Location	sex	N	% lipid	CB77 $pg \cdot g^{-1}$	CB126 $pg \cdot g^{-1}$	CB169 $pg \cdot g^{-1}$	CB105 $ng \cdot g^{-1}$	CB114 $ng \cdot g^{-1}$	CB118 $ng \cdot g^{-1}$	CB156 $ng \cdot g^{-1}$	Total TEQ $pg \cdot g^{-1}$	ΣPCB $ng \cdot g^{-1}$
Makkovik	F	1	91.3	38.1	71.6	14.9	3.8	0.3	13.2	2.2	10.2	670
	M	9	90.2	41.3	49.7	9.0	7.0	0.5	22.3	3.7	9.9	470
Nain	F	5	86.5	29.6	33.3	5.3	6.3	0.3	21.0	2.6	7.4	740
	M	5	85.6	28.5	31.2	6.6	7.2	0.4	23.4	2.3	7.4	560
Quaqtaq	F	5	89.2	29.8	37.7	9.6	18.3	1.3	55.1	3.5	13.1	380
	M	5	84.8	41.9	78.8	3.3	4.8	0.4	14.2	1.1	10.4	660

[1] TEQ= TCDD toxic equivalents calculated for each congeners using Toxic Equivalent Factors from Ahlborg *et al.* 1994.

kidney and liver of all seals analysed, as has been found previously for a large group of animals from the eastern Arctic analysed by Wagemann (1995). Arsenic levels, were low ranging from 0.017 to 0.024 $\mu g \cdot g^{-1}$ wet wt. in liver, however, results are presently available for only three locations.

Organochlorines

Low ($ng \cdot g^{-1}$ wet wt.) levels of organochlorines were detected in arctic char muscle (+ skin) from two locations in Labrador and three locations in Nunavik (Table 3). PCBs were the most prominent contaminants averaging 16 $ng \cdot g^{-1}$ wet wt. in samples from the two Labrador sites. Slightly lower ΣPCB levels (6-7 $ng \cdot g^{-1}$ wet wt.) were found in char muscle from Nunavik. The next most prominent group were the hexachlorocyclohexanes (HCH). The DDT group (see components listed in footnote of Table 3) were present at very low $ng \cdot g^{-1}$ levels. In general, these levels of persistent organochlorines are similar to or lower than reported in char muscle from Ungava Bay and Hudson Strait communities (Muir *et al.* 1997).

PCBs were also the major organochlorine contaminants in the 41 samples of ringed seal blubber, that were analysed (Table 4). Average concentrations of ΣPCB in blubber of males from 5 locations ranged from 472 to 980 $ng \cdot g^{-1}$ wet wt. and from 384 to 663 $ng \cdot g^{-1}$ in females. For samples from Nain and Makkovik, these results for 1998 were similar to levels reported for ringed seals from Nain collected by DFO in 1997 and analysed in the preliminary study (Muir *et al.* 1999). DDT-related compounds were also prominent contaminants in ringed seal blubber with average concentrations ranging from 192 to 670 $ng \cdot g^{-1}$ in males. ΣDDT levels appear to be higher in samples from the Ungava area than from Labrador but further statistical analysis taking into account age and blubber thickness is needed to confirm this. Similar concentrations of PCBs and ΣDDT to those in this study have been found in ringed seal blubber at other eastern Arctic locations (Muir 1998, Weis and Muir 1997).

Much lower levels of ΣPCB and other organochlorines were found in seal muscle and liver from animals from Nain (Table 4). Concentrations (both sexes) averaged 69 $ng \cdot g^{-1}$ in muscle and 120 $ng \cdot g^{-1}$ wet wt. in liver. Seal muscle is thus only slightly higher in ΣPCB than levels in freshwater fish and andromous fishes in the Canadian Arctic (Muir *et al.* 1997).

Coplanar PCBs were detectable in all 30 samples of ringed seal blubber (Table 5), although results for CB169 (3,3',4,4',5,5'-hexachlorobiphenyl) were below limits of quantification in several samples. Values of one-half the detection limit were substituted for non-detection results to calculate means. Toxic Equivalent concentrations (TEQs) were calculated for non-*ortho* (CB77, 126 and 169) and mono-*ortho* substituted congeners (CB105, 114, 118, 156) using Toxic Equivalent factors from Ahlborg *et al.* (1994). Average levels of TEQs were low in seal blubber ranging from 7 to 13 $pg \cdot g^{-1}$ wet wt. These levels of TEQs, and of individual coplanar PCBs, are comparable or lower than reported for ringed seals from Inukjuaq, the only other samples from Nunavik recently analysed for these compounds (Muir *et al.* 1995).

CONCLUSIONS

This report provides some of the first detailed data on heavy metal and organochlorine contaminants from Labrador and the Ungava region of Nunavik. Levels of heavy metals and organochlorines in seal tissues and char muscle from Labrador were generally found to be similar to those in Nunavik and other eastern Arctic locations (e.g. Baffin), however, there were a few differences. These included slightly higher levels of mercury in seal muscle and PCBs in char muscle (+skin) from Labrador compared to samples from Northern Quebec. Further statistical analysis is needed to confirm these preliminary observations.

Future work will concentrate on completion of analyses, e.g. metals, butyltins and organochlorines in mussels and char. Further work is planned for 1999/2000 to complete analyses, initiate further sample collections so that a more complete dataset is developed, and finally, to communicate this information to communities in the region.

Expected Project Completion Date: March 31, 2001

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TRENDS AND EFFECTS OF CONTAMINANTS IN POLAR BEARS

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OBJECTIVES

Long-term

1. To determine the effects, at the individual and population level, of persistent toxic organochlorine (OC) chemicals and their metabolites in the polar bear.
2. To determine the potential for exposure of the human population to persistent PCB and DDT metabolites through ingestion of wild foods.
3. To determine spatial and temporal trends of persistent and toxic organochlorine chemicals in a species at the top of the arctic marine ecosystem food web as an indication of the time constants and effectiveness of global controls of these chemicals.

Short-term

1. To complete the analysis of various existing data sets, including circumpolar data sets, to determine: regional patterns of persistent toxic organochlorine bioaccumulation and how this is influenced by sex and season; kinetics of organochlorine dynamics in individual bears and rates of transfer to cubs via milk; tissue distribution of methylsulfone PCBs in the polar bear food chain; and relative sensitivity of polar bears to effects of PCBs and mercury on lymphocyte proliferation.
2. To determine the immunotoxic effects of PCBs and other organochlorines in polar bears throughout a gradient of exposure (Hudson Bay, low; Svalbard, high) in collaboration with CWS Pacific and Northern Region, the Norwegian Polar Institute and the Norwegian Veterinary Institute. Antibody titre after vaccination with antigens will be compared to plasma contaminant concentrations, including PCB metabolites. Svalbard studies will be carried out in the summer of 1998. The Hudson Bay studies will be done in 1999.
3. To determine the significance of hydroxy-PCBs in PCB toxicology by: identifying structures of hydroxy-PCBs accumulating in plasma; relating these to exposure and metabolic capability of the species; developing a method for quantitative determination; and studying the effects of this class of compounds, especially on circulating thyroid hormone and vitamin A concentrations.

DESCRIPTION

It has been well documented that the polar bear is among the most highly organochlorine-contaminated of arctic mammals due to its almost exclusive diet of ringed seal. Monitoring of polar bear tissues for both organochlorines and heavy metals has been an important part of the Northern Contaminants Program (NCP) and the international Arctic Monitoring and Assessment Program (AMAP). Results to date have been included in the *Canadian Arctic Contaminants Assessment Report* (CACAR; Jensen *et al.* 1997) and the *AMAP Assessment Report* (AMAP 1998). However, these reports and other publications on the data have only begun to extract all of the potential information available. Considerable useful information on regional differences in patterns of congener makeup in the more complex groups of contaminants, such as PCBs and chlordanes, has yet to be gleaned. Preliminary analysis on the effect of age was reported in the 1997/98 Synopsis (Norstrom 1999). Furthermore, most of the data from a large study on seasonal variation in contaminant levels, effect of fasting on kinetics of organochlorines, and rates of transfer to cubs, remain to be analysed and prepared for publication. One of the principal objectives in this year was to complete as much as possible of these analyses.

Far less is known about the potential effects of organochlorines on polar bears than is known about levels and trends. Levels of organochlorines have not changed very significantly since the beginning of accurate population assessments in the early 1970s. Therefore, it is impossible to say one way or the other whether there are subtle effects on polar bear reproduction. Decreases in the number of polar bear cubs per potentially reproducing female showed steady declines in Hudson Bay throughout the 1970s, but have recently stabilized. This is probably due to ecologically-based factors (density dependent effects, weather, etc.), however, the presence of persistent organochlorines may also be a contributing factor. Norwegian scientists have noted a decrease in cub survival at Svalbard, and it has been suggested that PCBs may be involved (Bernhoft *et al.* 1996). Recent findings of several pseudohermaphrodite females in the Svalbard population have also raised concerns about the possiblity of endocrine disrupting compounds (EDCs) being the cause (Wiig *et al.* 1998). However, the incidence of this abnormality was also high in black bears from Alberta, presumably exposed to much lower levels of EDCs (Cattet 1988). Further research is therefore required to determine whether this is a normal occurrence in bears, or is related in some way to chemical exposure.

We have established that liver enzymes associated with exposure to dioxin-like compounds (CYP1A) are induced, and correlate with several PCB congeners in polar bears (Letcher *et al.* 1996). In the same study, we established that the more general mixed-function oxidase system induced by a number of organochlorines (CYP2B) is also induced, and correlates with a combination of PCB and chlordane levels. Toxic effects may be associated (or at least correlated) with these elevated enzyme levels, however, these findings are considered to be more an indication of exposure rather than of toxic effects. Further research is needed to study the effects themselves.

High body burdens of DDTs, $MeSO_2$-DDEs and $MeSO_2$-PCBs have been postulated as one possible explanation for a disease syndrome observed in Baltic Sea seals, characterized in part by adrenocortical hyperplasia (Olsson *et al.* 1994, Brandt 1994). In some cases, steroid metabolism *in vitro* was affected, suggesting the reactive metabolites may disturb adrenal glucocorticoid production *in vivo*. The cascade of effects could include reproductive impairment, bone erosion, and effects on the immune system. Polar bears metabolize DDE at a much higher rate than other species studied to date (Letcher *et al.* 1998), and elevated levels of 3-methylsulfone-DDE are found in liver (Letcher *et al.* 1992). Therefore polar bears may be subject to effects similar to those observed in Baltic Sea seals. Immune effects are considered to be the most sensitive endpoint of PCB (and probably other organochlorine) exposure so far studied in wildlife. Polar bears in eastern Greenland, the Svalbard Islands and a small geographical area in the Arctic Ocean near the entrance to M'Clure Strait in the Canadian Arctic archipelago have levels of PCBs (Norstrom *et al.* 1998) well above those found to cause immune dysfunction in seals (De Swart *et al.* 1994). Based on analysis of blood samples from Norwegian studies, it is probable that even higher concentrations of PCBs will be found in bears from the western Russian Arctic. Therefore, research on immune function in polar bears is a high priority. This research is also amenable to the study blood samples alone, because, unlike many other endpoints which require necropsy studies, this is feasible to do.

We previously reported on the proliferative response of polar bear lymphocytes to *in vitro* exposure to various PCB congeners (Norstrom 1999, Pagliarulo 1999, Pagliarulo *et al.* 1999). The results indicated that polar bears were insensitive using this immunological endpoint. Unexpected difficulties with clumping of cells and other methodological/logistical problems prevented more sensitive tests from being performed. Norwegian scientists had already launched an immunotoxicology study with male bears carried out in the summer of 1998 in Svalbard. The scope of this program was much larger than anything proposed so far in Canada, and included more sensitive endpoints; therefore it was agreed that a collaborative study should be initiated to take advantage of the already-developed methods and expertise. The immune response of polar bears from the high PCB-exposure area in Svalbard to vaccination with various antigens in 1998 will be compared to that of lower-PCB exposed bears from Cape Churchill in Hudson Bay in the summer of 1999. This will provide the exposure gradient needed to study PCB immunotoxicity dose-response relationships. The choice of study area and time is dictated by the necessity of recapturing the bears approximately 6 weeks after antigen exposure. The study is led by a Norwegian immunotoxicologist. Canadians will provide field and chemical analysis support as required in 1999.

Methylsulfone PCB metabolites have been thoroughly studied in polar bears. Their toxicological significance has not been established, but they are an important part of the total PCB suite of compounds, constituting approximately 6% of total PCBs in fat (Letcher *et al.* 1998), and approximately 11% in liver (Letcher *et al.* 1992). Hydroxylated PCBs are another important class of metabolites that may be involved in the expression of PCB toxicity. Some of these metabolites have been shown to interfere with vitamin A and thyroid hormone transport through binding with the plasma transthyretin (TTR) carrier protein (Brouwer and van den Berg 1986), as well as to cause drastic reduction in plasma thyroxin (T4) levels in rats, mice and marmoset monkeys (Brouwer *et al.* 1990). The mode of action was through competitive inhibition of T_4 binding to TTR in plasma; 4-OH-TCB bound 4 times more strongly than thyroxin. T_4 and 4-OH-TCB have very similar structures on one ring, i.e. one *para* hydroxy and two *meta* halogens (I in the case of T_4 and Cl in the case of 4-OH-TCB). Binding to the protein presumably prevents hydroxy-PCBs from being conjugated and excreted. Unlike methylsulfone PCBs, hydroxy-PCBs do not accumulate in fat or liver because there is no specific binding protein.

Hydroxy metabolites of the major PCBs: CB-105, CB-118, CB-138, CB-128, CB-156 and CB-170 are found in plasma of rats fed Aroclor 1254, and in Swedish grey seals and humans (Bergman *et al.* 1994). In most cases, the metabolites had the T4- like 4-hydroxy-3,5-dichloro substitution, indicating that they were probably bound to TTR in plasma. Concentrations of hydroxy-PCBs in human plasma were similar to those of the major PCBs, indicating highly selective binding. There is no competitive binding between hydroxy-PCBs and thyroxin to the main T4-carrier protein in human plasma (Thyroxin Binding Globulin, TBG). This is dissimilar to rats, where TTR is dominant (Lans 1995). However, TTR is still probably the main carrier protein for vitamin A (retinol) in all species. The importance of TTR in thyroid hormone homeostasis in polar bears is not known and needs to be determined. We previously reported on the identification of several hydroxy PCBs in polar bear plasma at concentrations in the $\mu g \cdot kg^{-1}$ (ppb) range on a plasma weight basis, which was the same order of magnitude as the PCBs themselves (Norstrom 1999, Sandau and Norstrom 1998). Pentachlorophenol and several unidentified halogenated phenolic compounds were also observed at measurable concentrations in plasma.

Therefore, there is reason to believe that exposure of polar bears to PCBs in the diet is affecting the plasma transport of T_4 and retinol via competitive binding of these compounds to plasma proteins. Skaare *et al.* (1994) found a negative correlation between total plasma PCB and retinol concentrations. Most of the information to date on the effect of hydroxy-PCBs is based on a relatively small number of mammalian species. The potential influence of hydroxy-PCBs in the homeostasis of thyroid hormones and vitamin A, and the interaction with related toxic effects (e.g. the effect of dioxin-like PCBs on hepatic vitamin A stores), are important in understanding PCB toxicity. A much better understanding of the importance of metabolites in PCB toxicity is required to unravel the multitude of toxic effects that PCBs can elicit.

As a continuance of our studies on the effects of PCB exposure on polar bears, we decided to investigate the interrelationships between retinol, T4, T3 and hydroxy-PCB concentrations in blood plasma from a high and a low PCB-exposed polar bear population in order to obtain a good dose-response relationship. Archived samples from the 1997 collection for immunotoxicology studies at Resolute were available as the low-exposure group. Norwegian scientists were enlisted to obtain blood samples from Svalbard in 1998 as the high-exposure group. Scott Brown at NWRI in Burlington undertook analysis of thyroid hormone parameters. Retinol and all chemical determinations were to be done at the National Wildlife Research Centre (NWRC). This study forms part of the Ph.D. research of Courtney Sandau at Carleton University, Ottawa, ON.

The above initiatives are directly in line with the recommendations from the *AMAP Assessment Report* (AMAP 1998).

ACTIVITIES IN 1998/99

Publication of Data

The major international study of distribution of organochlorines in polar bears was published (Norstrom *et al.* 1998).

Work on the multivariate analysis of the PCB and chlordane congener patterns from this study was completed and two papers were drafted for submission in 1999 (Duffe and Norstrom 1999a, 1999b).

The Ph.D. thesis by Susan Polischuk at the University of Saskatchewan on dynamics of organochlorines in polar bears was completed and defended (Polischuk 1999). Six papers will be drafted from this thesis and submitted for publication within the next fiscal year (Polischuk *et al.* 1999a,b,c,d,e,f).

The M.Sc. thesis by Marco Pagliarulo on proliferative responsive of polar bear lymphocytes to expsosure to PCBs and mercury was completed and defended (Pagliarulo 1999), and one paper drafted for submission in 1999 (Pagliarulo *et al.* 1999).

Polar Bear Immunotoxicology (Derocher, Wiig, Larsen, Skaare, Stirling, Norstrom)

In the Norwegian project «Klorerte organiske miljøgifter i isbjørn på Svalbard. Forekomst nivåer og effekter», immune globulin G (IgG) was rinsed from polar bears, and antibodies produced for these. Methods were established for quantifying immune globulin in polar bears. In addition, IgG was measured in blood samples collected in the period 1990-1996 and compared with the levels of PCBs in the same individuals. Antibodies for IgM and IgA (the main immune bodies of circulation and mucous systems) were produced. Methods for lymphocyte proliferation and cryo-preservation of white blood cells for immune function testing were completed.

The following activities were completed on 30 polar bears from Svalbard in the summer-autumn of 1998:

- Immunizing of polar bears, August 1998
- Recapture of vaccinated polar bears, September 1998
- Measuring of neutralized antibodies from herpes and influenza viruses
- Measuring of hemagglutination inhibition antibodies against influenza virus
- Measuring of antibodies against tetanus toxin
- Lymphocyte stimulation with mitogen and antigens
- *In vitro* exposure of lymphocytes with PCB congeners
- Lymphocyte proliferation in full blood and lymphocyte culturing technique development
- Cryo-preservation of lymphocyte cultures
- Lymphocyte proliferation in cryo-preserved cultures
- Phagocytosis and respiratory burst in cryo-preserved cultures using flow cytometric analysis methods
- Measuring of immune globulins
- Hematology
- Measuring of antibodies with environmental microbes
- hormone analyses (sex steroids and thyroid hormones)
- PCB measurements in fur samples and blood plasma

Hydroxy PCBs (Sandau, Burk, Brown, Trudeau, Derocher, Wiig, Norstrom)

A subset of available heparanized plasma samples from Svalbard (40) and Barrow Strait area (40) were chosen for analysis. The Svalbard samples were obtained by Norwegian biologists in the summer of 1998. The Barrow Strait samples were archived from the immunotoxicology studies performed by M. Pagliarulo in 1997. Good progress was made in the HO-PCB analysis, but the data will not be complete until the end of the summer, 1999 due to the complexity of the analyses. Preliminary data for 12 bears from each site is reported herein.

Total T4 and T3 as well as a free T3 and T4-binding index were measured in all of the 80 samples by S. Brown of NWRI , but the data were not complete in time to include in this report. Further statistical analysis is required. Retinol analyses were deferred to 1999/2000 due to lack of time to carry out the analyses on the part of the student.

RESULTS

Results from completion of the analysis of older data sets are presently being drafted. Two theses were defended, and nine papers are in various stages of being drafted. These are listed under "Activities", above. Submission of all papers is expected be completed by mid-2000. In addition, a study of methylsulfone PCBs in the polar bear food chain (cod, ringed seal and bear), which formed part of the thesis of Dr. R. Letcher at Carleton University in 1997 was published (Letcher *et al.* 1998). This study showed that the majority of methylsulfone PCBs found in polar bears are formed in ringed seal and bioaccumulated by the bear. This is the first demonstration of the bioaccumulation potential of these compounds. A study on the separation of chiral methylsulfone PCBs in the polar food chain was also published (Wiberg *et al.* 1998).

It is only possible to give a few of the more important results from study of the dynamics of organochlorines in polar bears. In Table 1, the whole body burdens (mg·animal^{-1}) and concentrations in fat (mg·kg lipid^{-1}) of organochlorines in pregnant females are compared to females with their cubs in the spring (March-May, 1992-1996). The mothers had significantly lower body burdens of all organochlorines than pregnant females. However, the concentrations generally were not significantly different between the two groups because the pregnant females had a higher lipid content than the mothers did. Even though body burdens decrease in the mothers during denning, the concentrations of only ΣDDT concentrations were significantly lower in mothers than pregnant females.

From sequential sampling of seven individual female bears over an average 188-day gestation and post-partum fast at Churchill, we have determined that they lose 42% of their mass, of which 55-66% is fat (Polischuk 1999). Comparison of organochlorine body burdens of the sequentially sampled females before and after denning indicated that there was significant excretion of organochlorines during gestation and lactation. The loss of PCB body burden ranged from 9-46% (mean 22%). The loss did not correlate with number of cubs, estimated length of nursing, or how much fat the female carried initially or lost during gestation and lactation. Furthermore, mass balance calculations could only account for about half the loss as transfer to cubs, on average. Although the females are fasting during lactation, the cubs are not. Excretion may therefore be occurring in the cubs' feces.

Data for males, females, cubs and yearlings during the summer fasting period at Churchill has shown that excretion of relatively slowly metabolized compounds, such as PCBs, does not occur when the digestive process is shut down (Norstrom 1999). However, excretion certainly occurs in feeding bears, presumably by partitioning into fecal matter, which is known to be the case for other animals. Decreases of compounds which are being metabolized occur during fasting. Thus DDTs (mainly DDE) decrease significantly during fasting in all sexes and ages. Chlordanes specifically decreased in males, but not in females during the summer fast,

Table 1. Mean (± SD) body burden (mg) and whole body concentrations (mg·kg^{-1}) of organochlorines (OCs) in pregnant females, mothers and cubs in spring. Body burdens for each group differ significantly from one another for all OCs (ANOVA $p<0.0005$). Seven of the females were captured as pregnant and again with cubs in spring, the mean number of days between capture was 188. Asterisks designate significant differences in whole body concentrations between pregnant females and mothers, and cubs and mothers in the spring (Tukey *$p<0.05$, ***$p<0.0005$).

	n	ΣClBzs	ΣHCHs	ΣCHLORs	ΣDDTs	ΣPCBs
Body burdens (mg)						
Pregnant	11	15 ± 6.1	23 ± 9.6	230 ± 68	28 ± 11	240 ± 79
Mothers	11	8.2 ± 2.4	8.1 ± 3.6	150 ± 47	6.0 ± 2.6	190 ± 65
Cubs	9	0.6 ± 0.4	0.3 ± 0.1	7.3 ± 3.7	0.2 ± 0.1	5.7 ± 3.0
Whole body concentrations (mg·kg^{-1})						
Pregnant	11	0.05 ± 0.02	0.07 ± 0.04	0.73 ± 0.25	0.09 ± 0.04***	0.76 ± 0.29*
Mothers	11	0.05 ± 0.02	0.05 ± 0.02	0.89 ± 0.29	0.03 ± 0.01	1.1 ± 0.37
Cubs	9	0.04 ± 0.03	0.02 ± 0.01	0.58 ± 0.31	0.02 ± 0.01	0.45 ± 0.25***

Table 2. Concentrations (ng·g^{-1} wet weight except where noted) of hydroxy-PCBs, PCBs, ΣClBzs, ΣDDTs, and thyroid hormones in blood of polar bears from Resolute and Svalbard.

	Geometric Mean	RESOLUTE minimum	N=12 maximum	Geometric Mean	SVALBARD minimum	N=12 maximum
4-HOB109	2.5	1.2	5.9	6.6	2.2	34
4-HO-CB146	7.4	1.3	23	15.8	5.0	120
4-HO-CB187	17	6.5	36	30	11	110
4-HO-CB172	1.9	1.0	4.6	6.5	3.0	20
Total HO-PCBs	58	31	140	138	74	490
CB 153	16	8.0	32	33	11	90
Total PCBs	38	19	69	94	35	250
Ratio HO-PCBs:PCBs	1.2	0.4	3.9	1.1	0.3	2.8
ΣClBzs	3.9	2.4	7.1	3.1	1.0	9.0
ΣDDTs	0.8	0.3	1.9	0.8	0.4	2.1
T4 (nmol·L^{-1})	6.5	0.9	15	1.1	0.2	7.6
T3 (nmol·L^{-1})	0.14	0.08	0.60	0.33	0.08	1.20

which accounts for the higher concentrations of this group of compounds in females. Ongoing metabolism during gestation and lactation (Table 1) probably accounts for the approximately 3-fold decrease in HCHs and DDTs, compared to a 20% loss of PCBs and 35% loss of chlordanes.

In spring, at the time of den emergence, the logarithm of mother's adipose tissue concentrations of OCs were significantly correlated ($p < 0.05$) with the logarithm of her milk OC concentrations (Figure 1). The slopes of the relationships were similar among chemicals, but less than one, indicating that transfer is allometrically related to concentration in adipose tissue. In general, the milk concentrations of the lower K_{ow} compounds, HCHs and ClBzs, had a greater tendency to be higher in milk than in adipose tissue on a lipid weight basis.

Mothers who had high OC concentrations in their milk in spring were recaptured in the autumn without cubs (Figure 2). In comparison, mothers with low OC concentrations in their milk in spring were recaptured in fall with cubs. The differences in concentrations were significant in all cases. For example, PCBs were approximately 3 times higher (6300 ng·g^{-1} lipid) in females that lost their cubs than in females that kept their cubs (1900 ng·g^{-1} lipid). It is not known how much significance can be attached to this finding in terms of reproductive performance, but it is suggestive, at least, that cub survival may be dependent on degree of exposure to organochlorines in milk.

In preliminary studies in Svalbard, IgG was found to be negatively correlated with PCBs (sum of 22 congeners). IgG is the sum of all antibodies of this type immune globulin in polar bear blood. This indicates that the PCB burden in polar bears has a much higher negative effect

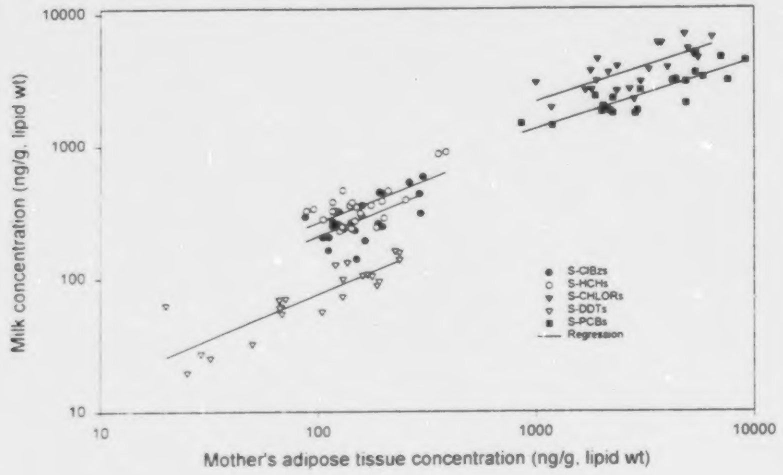


Figure 1. Relationship between OC concentrations in mother's adipose tissue and milk in polar bears.

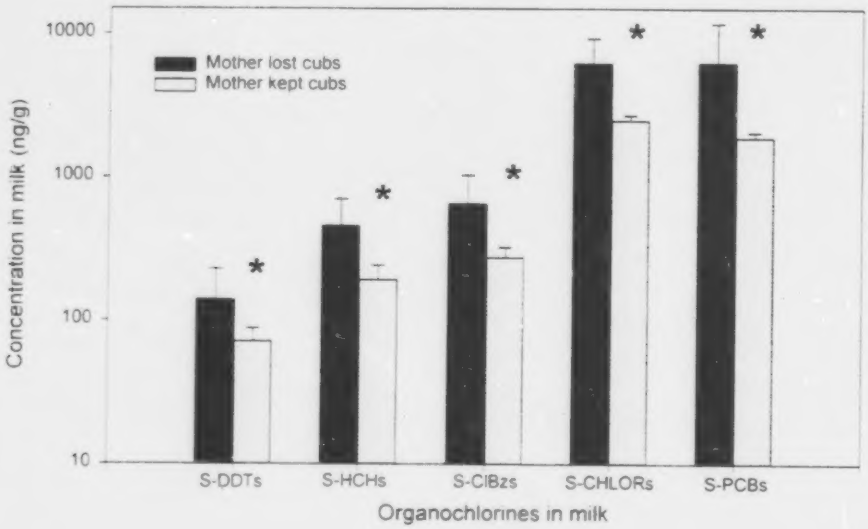
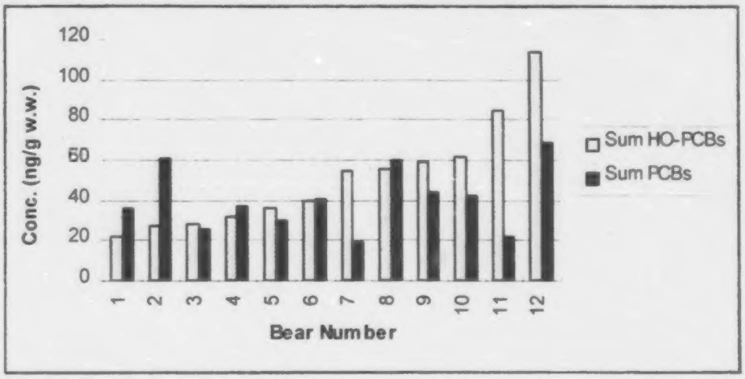
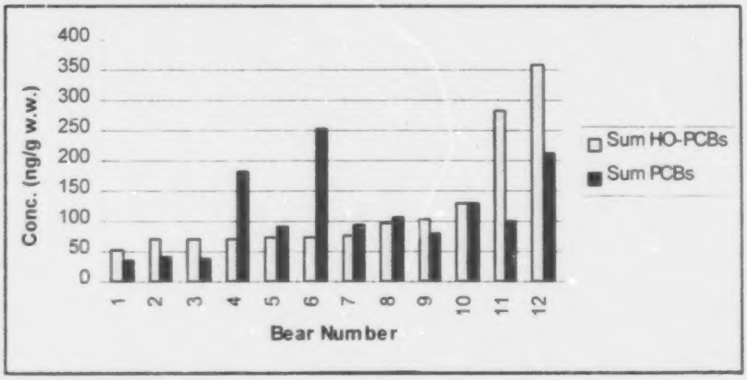


Figure 2. Concentrations (ng·g^{-1} lipid weight) of OCs in polar bear milk for mothers who lost and kept their cubs.



a) Resolute Bears



b) Svalbard Bears

Figure 3a & b. The concentration of total PCBs and total HO-PCBs in Polar Bears (n=12) from Resolute (a) and Svalbard (b). All concentrations are ng·g^{-1} wet weight.

on the immune system than we had expected. It is therefore very important to characterize the effects of organochlorines on the immune system of polar bears in detail. Documentation of immune suppressive effects and the implications these have on the resistance to infection and animal health of polar bears should be done in the Svalbard area. All the data indicated in 'Activities' above have been obtained from the Svalbard studies, but none were available from Norway for communication in this report. A summary of the combined Svalbard/ Hudson Bay studies will be reported next year at the conclusion of the project.

Positive identities have been established for four of the major hydroxy-PCBs found in polar bears. A liquid-liquid extraction method was adapted from the Bergman *et al.* (1994) method. Because fully ^{13}C-labelled internal standards were available from Wellington Laboratories, it was possible to quantify many of the compounds by isotope dilution GC-MS, as well as calculate recoveries. Recoveries were found to be excellent, generally > 85%.

The preliminary chemical residue data are summarized in Table 2. There are significant differences in contaminant levels and thyroid hormone levels between the two populations of polar bears. The Svalbard polar bears average 2.5 times the total PCBs and HO-PCBs blood levels compared to the Resolute bears. The main congeners of OH-PCBs vary considerably within the populations. The main metabolite in most of the samples is 4-OH-CB187 with geometric mean concentrations of 17.2 ng·g^{-1} and 30.2 ng·g^{-1} (whole plasma weight) in Resolute and Svalbard bears, respectively. The ratio of total HO-PCBs to PCBs is not significantly different between the two populations. However, the ratio was highly variable among individuals within each population (Figure3 a, b).

The T4 levels are 6 times higher in the Resolute bears than the Svalbard bears (Table 2), which may be an indication of interference with T4 transport by hydroxy-PCBs, or interference with thyroid hormone deiodinase activity in liver. The preliminary retinol data indicate a similar overall lower level in the Svalbard population, which may support the theory that competitive binding of hydroxy-PCBs and T4 to TTR is occurring. Much firmer conclusions can be made when the data set is complete in the 1999/2000 fiscal year, and a proper statistical analysis can be done.

One complication is that GC-MS analysis indicates the presence of many more phenolic compounds than the hydroxy-PCBs. The largest single phenolic is an early-eluting heptachloro compound. Pentachlorophenol is also present, in addition to a number of other minor halogenated compounds. These are all probably bound to TTR. In order to study the effect of chlorinated phenolic compounds on T4 and retinol homeostasis, these compounds will have to be considered.

Further work is planned on confirming the presence of TTR in polar bear plasma (University of Wageningen, The Netherlands) and identification and TTR binding capacity of the major unknown heptachloro compound.

DISCUSSION, FUTURE ACTIVITIES

It is hoped that all of the results for the various studies under NCP-I, as indicated in 'Activities', above, will be submitted for publication before the end of the next fiscal year.

Three major thrusts in identification of the effects of organochlorines on polar bears are either ongoing, or funded for the next fiscal year, and will be reported at that time.

The first is the second phase of the immunotoxicology study. It should reveal whether there is a significant difference between the immunocompetence of Canadian and Svalbard bears, whether this correlates to organochlorine exposure, and if the bears (at least in Svalbard) are at risk.

The complete data set on hydroxy-PCB, organochlorine, T4, T3, and retinol concentrations will be obtained and analysed to determine any significant correlations. Hopefully, a preliminary risk assessment based on these findings can be made.

Studies will be initiated on stored polar bear microsomes to investigate the effect of organochlorine exposure on rates of testosterone metabolism and patterns of metabolites in males. Metabolism of individual PCBs and natural mixtures of PCBs from ringed seal will also be studied with these microsomes to determine the overall structure-activity relationships for PCB metabolism.

Expected Project Completion date: 2001

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SOURCES, PATHWAYS AND LEVELS OF CONTAMINANTS IN FISH FROM YUKON WATERS

Project Leader: Mark Palmer, Chair, Yukon Technical Committee on Contaminants in Northern Ecosystems and Native Diets

Project Team: Government of Yukon Fisheries; Department of Fisheries and Oceans;
Department of Indian Affairs and Northern Development;
Environment Canada; Council of Yukon First Nations

OBJECTIVES

1. To determine levels of contaminants for long term trend analysis.
2. To verify results from previous organochlorine analyses in order to address concerns raised by health advisories based on existing data.

DESCRIPTION

Burbot liver and lake trout flesh samples from headwater lakes in the Yukon River system (Tagish, Laberge, etc.) in the early 1990's had elevated levels of organochlorine industrial chemicals and pesticides. In response to elevated toxaphene levels, Health Canada issued a public health advisory on Laberge and Atlin lakes. The advisory recommended that consumption of lake trout flesh be limited on Lake Laberge and that burbot livers not be consumed on Lake Laberge and limited on Atlin Lake. This has affected the various fisheries on the lakes, and generated considerable concern from residents who used the fisheries resources throughout the Yukon.

The primary purpose of the 1991-1999 fish survey was to assure Yukoners of the safety of fish for human consumption. For this reason, sampling was used to survey fish stocks that are important to First Nations fisheries. Lake trout and whitefish were the species sampled in most lakes, as these fish are widespread and commonly eaten. Burbot livers, which are a traditional First Nations food, were sampled where possible. Arctic grayling and northern pike were sampled in Lake Laberge and at several other locations for comparison. In 1993, salmon samples were taken from important native fishing areas and from the Whitehorse Fishway.

ACTIVITIES AND RESULTS

Since 1991, fish have been sampled from lakes and rivers throughout the Yukon (see Figure 1). Yukon First Nations recommended sampling locations and fish species, based on traditional uses of fish and on community concerns. Additional lakes were chosen to provide broader geographic coverage. Fish samples were analysed for organochlorine concentrations (DDT, HCH, HCB, chlordane, PCBs, Mirex, dieldren and toxaphene) by Axys Analytical laboratories in Sidney, British Columbia and at the Department of Fisheries and Oceans laboratory in Winnipeg, Manitoba.

Methods and results of analyses of fish muscle tissue and burbot liver samples collected through this program are presented in more detail in recent Northern Contaminants Program documents (Yukon Contaminants Committee [YCC] 1997, Muir *et al.* 1997) and in a Yukon Contaminants Committee data report (Yukon Contaminants Committee *in press*).

In 1998 the YCC sampled lake trout and burbot from Lake Laberge as part of the Lake Recovery Program. Samples of burbot liver and trout muscle tissue are in the process of being analysed for organochlorines. The intent is to confirm the downward trend confirm for some organochlorines, and to evaluate the need for the existing health advisory.

Lake trout and burbot were also collected from Quiet Lake as part of the trend monitoring program. Samples from Quiet and Kusawa Lakes as well as salmon from three locations will be collected annually starting in 1999.

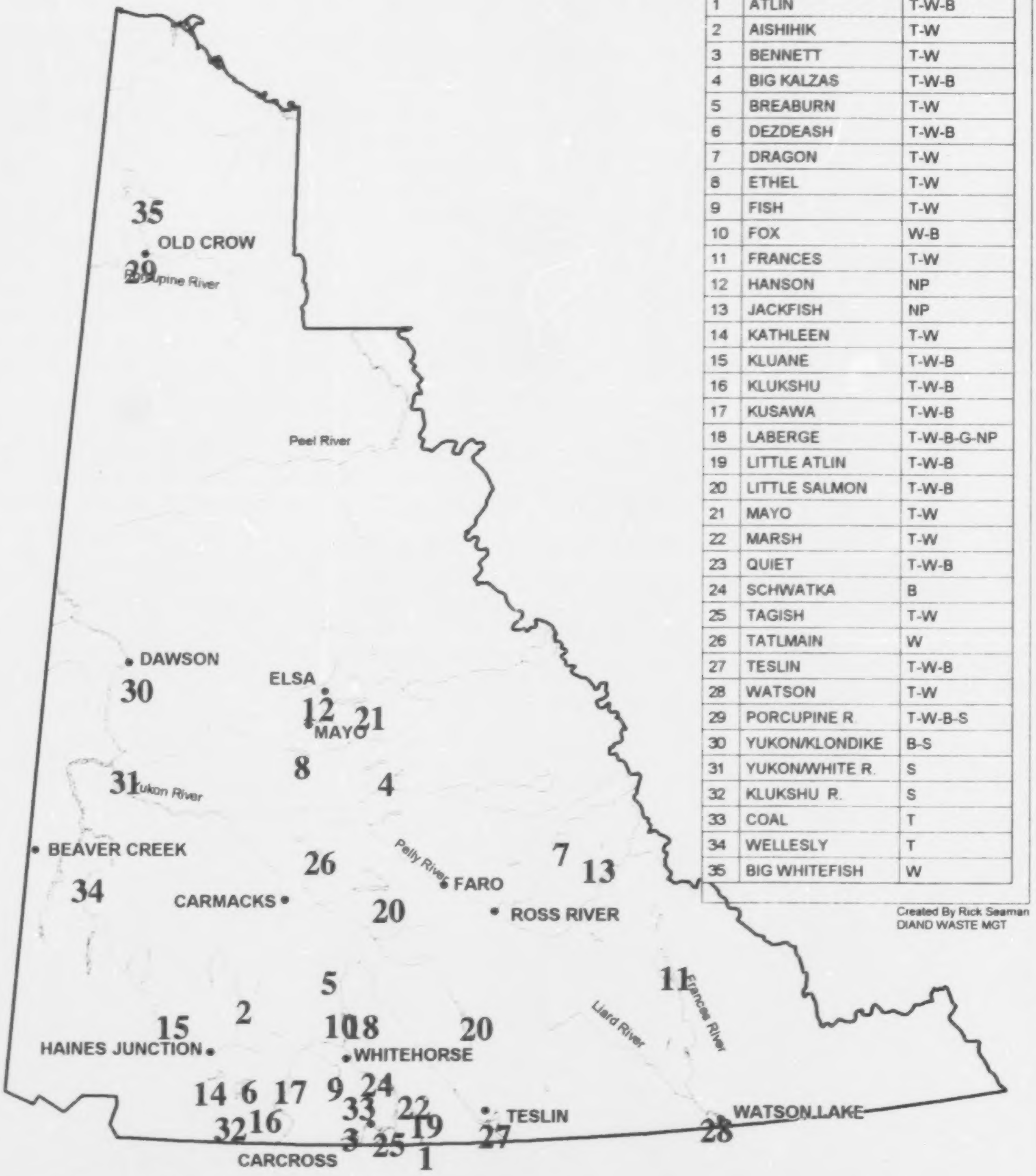
DISCUSSION/CONCLUSIONS

Main findings of the multi-year program include:

- Organochlorines such as toxaphene, PCBs, ΣDDT, Σchlorobenzenes, ΣHCH, and Σchlordane are present in lakes and rivers throughout the Yukon, as in other regions of the circumpolar North.
- Yukon whitefish, Northern pike, Arctic grayling, and salmon have consistently low levels of organochlorines and have not resulted in any health advisories.
- Lake trout organochlorine contaminant levels vary a lot from lake to lake and within lakes, partly in relation to whether or not the trout eat fish or invertebrates.

YUKON FISH SAMPLING LOCATIONS

1991 - 1999


35
OLD CROW
29
Porcupine River
Peel River
DAWSON
30
ELSA
12
21
MAYO
8
4
31
Yukon River
BEAVER CREEK
26
Pelly River
FARO
7
13
34
CARMACKS
20
ROSS RIVER
5
11
Frances River
Liard River
2
15
10
18
20
HAINES JUNCTION
WHITEHORSE
14
6
17
9
24
33
22
TESLIN
32
16
19
3
25
27
28
WATSON LAKE
1
CARCROSS

NO	WATERBODY	FISH
1	ATLIN	T-W-B
2	AISHIHIK	T-W
3	BENNETT	T-W
4	BIG KALZAS	T-W-B
5	BREABURN	T-W
6	DEZDEASH	T-W-B
7	DRAGON	T-W
8	ETHEL	T-W
9	FISH	T-W
10	FOX	W-B
11	FRANCES	T-W
12	HANSON	NP
13	JACKFISH	NP
14	KATHLEEN	T-W
15	KLUANE	T-W-B
16	KLUKSHU	T-W-B
17	KUSAWA	T-W-B
18	LABERGE	T-W-B-G-NP
19	LITTLE ATLIN	T-W-B
20	LITTLE SALMON	T-W-B
21	MAYO	T-W
22	MARSH	T-W
23	QUIET	T-W-B
24	SCHWATKA	B
25	TAGISH	T-W
26	TATLMAIN	W
27	TESLIN	T-W-B
28	WATSON	T-W
29	PORCUPINE R	T-W-B-S
30	YUKON/KLONDIKE	B-S
31	YUKON/WHITE R.	S
32	KLUKSHU R.	S
33	COAL	T
34	WELLESLY	T
35	BIG WHITEFISH	W

Created By Rick Seaman
DIAND WASTE MGT

- Burbot (lingcod) all have very low levels of organochlorines in their muscle tissue, but contaminants build up in the large, fatty livers. Contaminant levels also vary a lot from lake to lake.

Project Completion Date: Ongoing

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YUKON LOCAL CONTAMINANTS CONCERNS PROGRAM

Project Leader: Patrick Roach, Contaminants and Waste Management Division,
Department of Indian Affairs and Northern Development (DIAND), Whitehorse, YT

Project Team: Yukon Contaminants Committee; various other stakeholders involved in the individual projects

OBJECTIVES

1. To address local concerns related to contaminated sites.
2. To evaluate individual sites and determine the responsible authority or stakeholder.

DESCRIPTION

The Local Contaminants Concerns (LCC) Program in the Yukon, which receives direction from the Yukon Contaminants Committee (YCC), is intended to address a range of community concerns related to suspected local contamination sources. In addition to planned projects, a number of projects/concerns arise annually during the course of the year. These unplanned projects, referred to as "walk-ins", are dealt with as they arise. Typical walk-in projects are local concerns, which are brought to the attention of the LCC either through a phone call or a direct visit to the office by concerned members of the public. In some years, walk-ins may represent a significant portion of the LCC operation.

In practice, the LCC investigates sites that have been identified either through previous planning or the "walk-in" route, and deals with the investigation results in a number of ways. If the site investigation reveals a level of contamination or a specific contaminant that is in violation of existing regulations, the LCC turns the site and the investigation results over to the appropriate regulatory agency for action. If the site is non-regulatory in nature and is on lands for which the federal government is responsible, the investigation is turned over to the DIAND Waste Management Program for action. In many instances, there is no significant contamination and a report is sent to the appropriate person or agency, documenting the results.

This process allows the LCC to fill in gaps within existing Federal and Yukon government programs, and supplements the activities of the Northern Contaminants Program (NCP).

ACTIVITIES IN 1998/1999

A large number of investigations were conducted during the 1998/1999 fiscal year. Three examples have been selected as representative of LCC activities.

Arctic Gold and Silver Mine Site

The Waste Management Program initiated a preliminary investigation of the abandoned Arctic Gold and Silver mine site located directly south of the community of Carcross, in anticipation of a project to eliminate environmental impacts from the tailings. The LCC was approached by the local Carcross Tagish First Nation to determine what off-site impacts had occurred from the transport of arsenic from the tailings.

Samples of vegetation from the area downstream of the tailings and sediments from the mouth of an impacted creek were collected and sent for analysis of arsenic content. Arsenic in the sediment samples were found to be representative of the local region, however, results of arsenic levels in the vegetation were more ambiguous. For comparison purposes, Dr. Miriam Diamond at the University of Toronto was contracted to provide a literature search of available information on arsenic levels typical of various species of vegetation.

The arsenic levels in vegetation collected at the impacted area of the mine site were similar to levels in vegetation at other contaminated sites, as reported in the literature search. All of the vegetation that was suitable for human consumption had low levels of arsenic and was near the average of 0.2 ppm reported for food in the United States. Any practical consumption would not exceed the 182 µg per day, as recommended by the World Health Organization. Still, arsenic levels in some of the grass and willow samples were elevated and may represent a pathway for arsenic transport to the local wildlife.

Results

A copy of the report from M. Diamond has been distributed to the Carcross Tagish First Nation and relevant government agencies. A detailed comparison of the arsenic levels in local vegetation with data from the literature is in progress.

Ross River Site Investigations

The Ross River First Nation expressed concerns directly to the LCC Program and the Land Claims negotiators, related to several local sites within their traditional territory. In discussions between the Ross River First Nation, Land Claims staff, and the LCC, three sites were selected for evaluation.

(i) Whiskers Lake Coal

The site of an old coal mine near the town of Ross River was raised as a concern due to suspected metals leaching from the site of the old open pit and affecting Whiskers Lake, as well as dust from the site blowing into town. The site was inspected by LCC staff and samples of the pit water, coal, waste rock, and lake water were collected and sent for analysis. There was no dust problem identified at the time, however some restoration of the area where the waste rock is contained was recommended. Analysis of water samples and solids indicated that there was no metal transport problem associated with the old mine workings and that the site posed no risk to the nearby lake.

(ii) Jackfish Lake

Jackfish Lake is located southeast of Ross River and was used as a camp site and a float plane base during the Second World War construction of the Canol Pipeline. There were anecdotal reports of a large quantity of barrels that had been dumped into the lake by the US Army during this time. A number of barrels were visible from the existing float plane base on the lake and it was decided to conduct an underwater survey of the lake to inventory any barrels that might be present. A local contractor was hired to conduct the survey and collect any suspect debris from the lake. The survey located only a few barrels concentrated around the existing dock area, and one bucket containing tar/asphalt material was removed from the lake. Fish samples, which had been previously collected under the NCP, were sent for analysis for organochlorines. The fish analysis produced values comparable to other lakes in the Yukon where there had been no direct application of pesticides.

(iii) Municipal Dump and Sewage Pit

The Ross River First Nation complained that a local dump and a sewage pit was contaminating one of their water supplies. After some investigation by LCC staff, it was discovered that an old dump (circa 1960s) had been located in a ravine from which spring water had been traditionally collected for drinking during the summer months. Some years later, a sewage pit had also been constructed at the site.

LCC staff contacted the Yukon government and, with their assistance, wells were installed on the site to collect samples of the groundwater. Of four wells installed, only one produced a contaminated sample. The analysis of the sample indicated either weathered fuel oil or lubricating oil in the groundwater. The samples were also analysed for DDTs since the dump operated during the spraying program in the Yukon, but no evidence of these compounds was detected. As the site is still within a regulated lease, the results were turned over to the Water Resources and Lands Divisions of DIAND for possible regulatory action. The LCC agreed to conduct one additional sampling of the site in 1999 in order to determine if the contamination identified was transient. If contamination is still present, the Yukon government will conduct a larger evaluation of the site.

Results

All of the results are summarized within one publication (Roach 1999) which was distributed to the Ross River First Nation, Land Claims negotiators, and the Yukon government.

Carcross Pentachlorophenol

A rail tie treatment plant was located on the Nares River at Carcross, Yukon waterfront from the late 1940s until 1975. The site was later found to be heavily contaminated with chlorophenol compounds, dioxins and furans. Originally an investigation by the Water Resources Division of DIAND, the site clean-up was directed by the Yukon government, through their Contaminated Sites legislation.

The local Carcross Tagish First Nation was concerned about off-site migration of the contamination and how it may have affected the fish species in the area. A sampling program was initiated by the LCC, with assistance from Water Resources, the Carcross Tagish First Nation, and the Freshwater Institute of the Department of Fisheries and Oceans (DFO), to conduct a survey of sediments in the area. Samples were collected upstream, adjacent and downstream of the site for aerosol dispersion monitoring. The analysis included chlorophenols, their anisoles, dioxins and furans. Coal Lake, which had not been directly impacted by chlorophenols, was selected for sediment sampling as a control lake. The results indicated an increase in chlorophenol, dioxin, and furan levels that diminished upstream and downstream of the site. All of the recorded levels were below any level that would require action by a regulatory agency.

Fish that had been collected under the NCP and additional fish collected under LCC were sent for analysis. The levels of chlorophenols, dioxins and furans were within accepted limits. However, the anisoles of the chlorophenols were of a much higher concentration than the levels for the chlorophenols themselves. Despite a thorough search, no information regarding consumption guidelines for anisoles was found. This issue has been referred to the Centre for Indigenous Peoples' Nutrition and Environment (CINE) and Health Canada for further consideration.

Results

A comprehensive report on all of the sediment and fish studies has been produced (Roach *et al.* 1999) and distributed to the Carcross Tagish First Nation, Land Claims negotiators, DFO, Environment Canada, and the Yukon government.

DISCUSSION AND CONCLUSIONS

This is the first year for the LCC program and the results to date have been satisfactory to the YCC. The LCC has met the mandate of providing a cost-effective response to the concerns of the Yukon public regarding contaminants in the local environment. As the program matures, the nature of it will change to accommodate the direction of the YCC and operational requirements.

The YCC allows enough flexibility within the LCC for it to respond to local concerns in a timely manner. The benefits are better public involvement and a greater sense of ownership in the results. In addition, the input from outside the Program allows us to identify sites that might otherwise be missed and fit them into the Waste Management Program.

Project Completion Date: Ongoing.

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SAHTU CARIBOU/MOOSE SAMPLING PROGRAM

Project Leader: Sahtu Dene Council

Project Team: Deline Renewable Resource Council; Fort Good Hope Renewable Resource Council; Tulita Renewable Resource Council; Colville Lake Renewable Resource Council; Fort Wrigley Renewable Resource Council; Department of Resources, Wildlife, and Economic Development (RWED), GNWT, Sahtu Region; Dene Nation, Environmental Manager; David Kennedy, Contaminants Division, Department of Indian Affairs and Northern Development (DIAND); Colin Macdonald, Consultant, Northern Environmental Consulting and Analysis (NECA), Pinawa, MB

OBJECTIVES

1. To assess the levels of exposure to the three main types of contaminants (organochlorines, heavy metals and radionuclides) in caribou/moose in the Sahtu region.
2. To address the concerns of the region regarding the safety of consuming caribou/moose, which is the mainstay of their traditional diet.
3. To provide baseline data on the contaminant levels in caribou/moose.
4. To compare the results of the findings to the baseline levels and spatial trend results of the 1995 NWT caribou studies.

DESCRIPTION

This project was initiated by a request made at the Mackenzie Basin Community planning workshop held in Tulita, NWT on January 19-20, 1998. The Sahtu communities identified that caribou/moose were the most important species to the diet of the communities and that it was the most common species consumed by all in the region. An agreement was made at that meeting that caribou/moose should be sampled in the region. The locations were to be identified by each of the respective communities depending on their local harvesting areas for each of the species. Sampling has been conducted in other areas of the North, both east and west of the Sahtu, however, with the exception of a study by the Department of Fisheries and Oceans (Muir *et al.* 1989), little sampling has been done in the Sahtu region.

ACTIVITIES IN 1998/99

An environmental coordinator (John T'seleie followed by Leroy Andre) was hired to oversee the project and to coordinate the collection of samples by hunters in the communities and to ship the samples south for analysis. The consultant (C. Macdonald, NECA) was responsible for coordinating the analysis with the laboratories and collating the data. Administrative support was also provided by D. Kennedy of the Contaminants Division, DIAND.

Workshops were held in each of the Sahtu communities to discuss the results of the study, to discuss contaminants in the North and Northern Contaminants Program (NCP) activities, and to address any questions. A copy of an illustrated report summarising the results, and containing general information about contaminants was left with the Resource Council or Band Manager in each community for future reference (Macdonald 1999).

Moose and caribou were collected by hunters in the Sahtu in December 1998 and January 1999. The communities involved in the study and the areas from which the samples were taken are shown in Figure 1. Field sheets were filled out for all samples but one. Samples were stored in clean WhirlPak® bags (sent north for this study) and shipped to the Sahtu environmental coordinator in Deline (Leroy Andre). The samples were stored frozen until they were shipped south for analysis. Muscle samples were analysed for metals and radionuclides, while kidneys were analysed primarily for metals and liver was analysed for radionuclides.

Metals were analysed by ICP/MS following wet digestion by Envirotest Laboratories, a CAEAL (Canadian Association for Environmental Analytical Laboratories) accredited laboratory in Edmonton, AB. Radionuclides were analysed by Whiteshell Laboratories in Pinawa, Manitoba, following routine protocols for freeze-drying and/or ashing samples. Samples were analysed for gamma-emitting radionuclides using a p-type well-

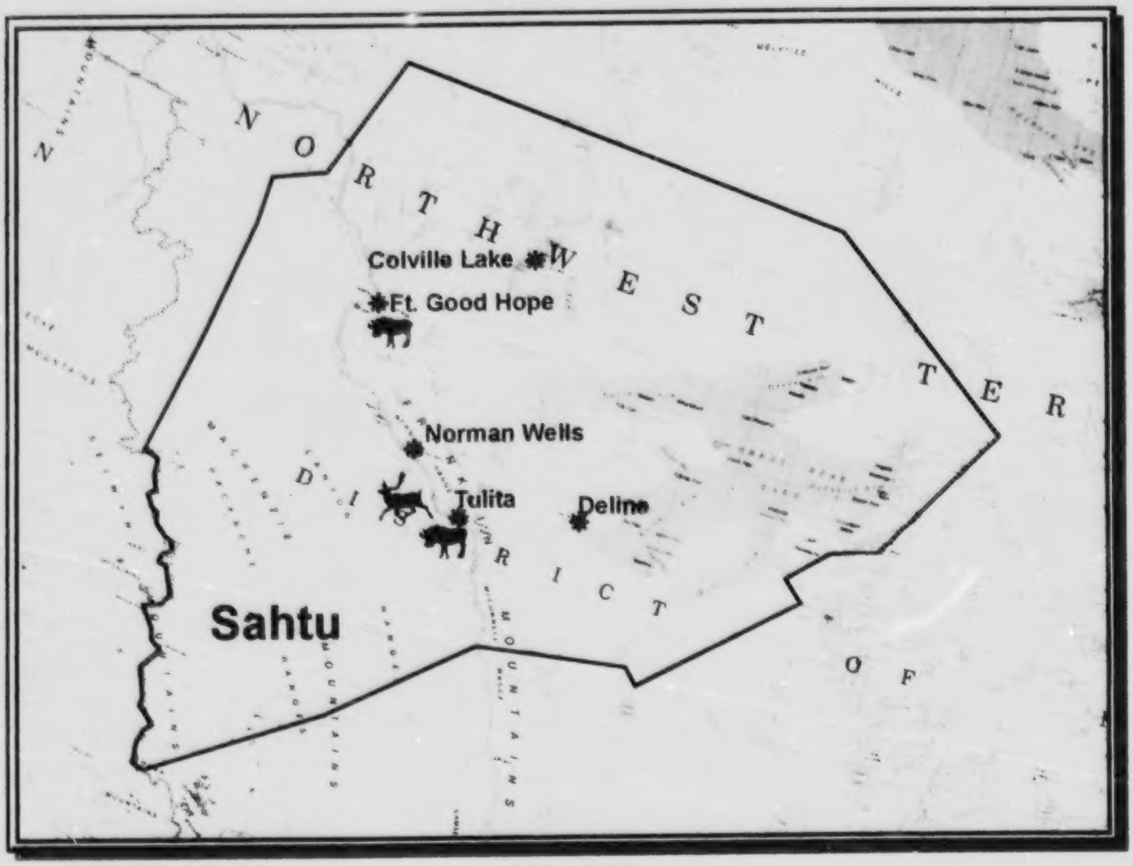
N O R T H W E S T T E R
Colville Lake
Ft. Good Hope
Norman Wells
Tulita
Deline
D I S T R I C T
Sahtu
O F

Figure 1. Map of the Sahtu region showing the participating communities and the areas where the moose and caribou were collected

detector, with count times of up to 14 hours. The detector was calibrated using standard gamma sources with the geometry and density of the sample. The same samples were analysed for ^{210}Po by alpha spectrometry, after digestion and deposition onto silver discs, using ^{209}Po as a tracer. The ^{210}Po concentration at the day of sampling was calculated by adding the supported (^{210}Pb concentration) and unsupported fractions (backdated to the date of plating from the counting date). QA/QC was conducted using duplicates, blanks and spiked samples and reference sources. Organochlorine pesticides in fat samples were analysed by the Great Lakes Laboratory at the University of Windsor with GC/ECD using standard protocols. The laboratory is CAEAL accredited and takes part in interlaboratory tests through the National Wildlife Research Centre (NWRC) laboratories in Hull, QC.

RESULTS

The list of samples collected, the hunters and the area of collection are listed in Table 1. In total, six moose were taken in the study. Two woodland caribou were taken near the Little Keele River, however, because the caribou had moved deeper into the mountains at the time of collection, no further woodland caribou were collected. However, the data from these two caribou corresponds with data from other studies and the small number of caribou collected is not expected to significantly influence the conclusions of the study. Summaries of the data for the three classes of contaminants are presented in Tables 2, 3 and 4.

Metals

The metal analysis provided a comprehensive list of elements in kidney and muscle. The scan reported the levels of 27 metallic elements, five of which (antimony (< 0.04 $mg \cdot kg^{-1}$ dry weight (wt.)), arsenic (< 0.2 $mg \cdot kg^{-1}$ dry wt.), beryllium (< 0.2 $mg \cdot kg^{-1}$ dry wt.), thallium (<0.04 $mg \cdot kg^{-1}$ dry wt.) and vanadium (<0.08 $mg \cdot kg^{-1}$ dry wt.), were below detection limits in all samples.

It is difficult to draw firm conclusions concerning the status of contaminants in moose and caribou in the Sahtu because of the small number of samples analysed in this study and the large, geographically diverse area of the Sahtu. Comparisons with other studies indicate that the levels of most metals are similar to, or lower than, moose and caribou outside the Sahtu. For example, background levels of zinc in liver and kidney of deer in the U.S. are in the range of 130 to 170 $mg \cdot kg^{-1}$ dry wt., but increase markedly to greater than 250 $mg \cdot kg^{-1}$ near a zinc smelter in Pennsylvania (Sileo and Beyer 1985). Similarly, moose collected in Norway showed levels of 88 to 120 $mg \cdot kg^{-1}$ dry wt. (assuming a dry:wet ratio of 0.25), including a site near a nickel smelter (Sivertsen *et al.* 1995). The levels of 131.6 $mg \cdot kg^{-1}$ in liver and 161.0 $mg \cdot kg^{-1}$ in kidney for moose and 62.3 $mg \cdot kg^{-1}$ in liver and 125.5 $mg \cdot kg^{-1}$ in kidney for caribou in the Sahtu (Table 2) are well within the range of values considered to be background elsewhere.

Several studies have been conducted on copper in moose in Sweden because of the likelihood of copper deficiency caused by the leaching of copper from soil with low pH precipitation. Copper is a required micronutrient and a deficiency can result in major effects in the nervous and digestive systems (Frank 1998). A survey of moose in Sweden between 1982 and 1992 (Frank 1988) reported background copper levels in moose liver of 120 to 130 $mg \cdot kg^{-1}$ wet wt. (assuming a dry:wet wt.ratio of 0.25), which corresponds closely to the level of 117 $mg \cdot kg^{-1}$ wet wt. in moose liver in the Sahtu. Average concentrations as high as 232.7 $mg \cdot kg^{-1}$ dry wt. (n=51) have been observed in some regions in Finland (Hyvärinen and Nygrén 1993). White-tailed deer living close to a zinc smelter in Pennsylvania showed mean liver concentrations of 190 $mg \cdot kg^{-1}$ wet wt., with one individual as high as 448 $mg \cdot kg^{-1}$ wet wt. (Sileo and Beyer 1985), much higher than those in the Sahtu. Molybdenum, an element which can interfere with copper uptake and cause molybdenosis, is at a mean level of 4.8 $mg \cdot kg^{-1}$ dry wt. in Sahtu moose which is at the upper range of values suspected to cause copper deficiency in moose in Sweden (Frank 1998). These comparisons indicate that copper levels are within a reasonable range for large herbivores, however, the relationship between copper and molybdenum in moose in the Sahtu may warrant further study.

The levels of cadmium in moose kidney (99.2 $mg \cdot kg^{-1}$ dry wt.) are consistent with the levels found in Yukon moose and are at the high end of the values reported in the literature. In a large survey of metals in large mammals in the Yukon, Gamberg (1996) reported an average kidney Cd concentration of 133.8 $mg \cdot kg^{-1}$ dry wt. (n = 63), with one individual approaching 550 $mg \cdot kg^{-1}$ dry wt. These levels are clearly higher than background levels in southern Canada for moose of equivalent ages (Gamberg 1996, Glooschenko *et al.* 1988, Crête *et al.* 1987). In southern Quebec, the highest average level reported for moose kidney in a particular area was 100 $mg \cdot kg^{-1}$ dry wt. (17 females; Crête *et al.* 1987), similar to the level reported by Glooschenko *et al.* (1988) for un-buffered soils (although one region in Ontario had considerably higher kidney levels of about 200 $mg \cdot kg^{-1}$ dry wt. in adults). The average value of Cd in the Sahtu and the high level of 168 $mg \cdot kg^{-1}$ wet wt. found in one individual indicates that Cd levels are probably slightly lower than those in the Yukon, although it would take a much larger survey to determine how much lower. The Cd levels found in the two caribou are low relative to the moose from the same area and are within the range reported for barren ground caribou in the western NWT.

Table 1. Summary of collection data for moose and woodland caribou collected in the Sahtu region in 1998/99.

Sample ID	Collected by	Collection Date	Harvest Location	Sex	Approx. Age	Tissues	Comments From Hunters
Moose							
TM-2	Peter Horassi	Dec. 9, 1998	Blue Fish Creek	male	adult	fat, liver, kidney, muscle	
TM-4	William Horassi	Jan. 14, 1999	25 Mile Island	male	adult	fat, liver, kidney, muscle	
GHM-1	Jean Marie Rabisca	Jan. 25, 1999	Rory Lake	male	young adult	fat, liver, kidney, muscle	young bull (2 or 3 years)
GHM-2	Lawrence Manuel	Jan. 26, 1999	Gillis River	male	young adult	fat, liver, kidney, muscle	3-year-old male; good condition
SCM991	Jim Wrigley	–	3 km north of Keele River	female	adult	fat, liver, kidney, muscle	
M994	–	–	–				
Woodland caribou (Mackenzie Mountain herd)							
SAWC991	Richard Popko	Feb. 21, 1999	Little Keele River	female	adult	fat, liver, kidney, muscle, lungs	good condition; backfat about 0.5 cm thick;
SAWC992	Richard Popko	Feb. 21, 1999	Little Keele River	female	adult	fat, liver, kidney, muscle, lungs	good condition; samples fresh frozen

Table 2. Average (with standard deviation) metal concentrations in moose and woodland caribou collected in the Sahtu in 1998/99. Other metals which were measured but were undetected were (followed by the detection limit): antimony (DL = 0.04 mg·kg^{-1}); arsenic (DL = 0.2 mg·kg^{-1}); beryllium (DL = 0.2 mg·kg^{-1}); silver (DL = 0.08 mg·kg^{-1}); thallium (0.04 mg·kg^{-1}); vanadium (DL = 0.08 mg·kg^{-1}). Concentrations are in mg·kg^{-1} wet weight.

	Al	Ba	Bo	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	Sn	Zn
Moose (n = 6)																					
Kidney	7.0	1.0	4.5	99.2	568	1.0	0.3	15.5	356	0.06	855	23.1	2.0	0.4	10120	13450	3.4	7200	0.9	16.5	161.0
	(3.4)	(0.5)	(1.0)	(60.4)	(188)	(0.4)	(0.1)	(1.7)	(135)	(0.05)	(90)	(5.3)	(0.4)	(0.1)	(280)	(864)	(0.5)	(1255)	(0.6)	(1.6)	(47.2)
Muscle	20.0	0.4	3.7	0.1	169	1.3	<0.08	5.2	211	0.1	1143	1.0	0.9	0.5	7670	15260	0.3	1970	0.14	14.9	172.6
	(5.6)	(0.2)	(0.4)	(0.04)	(60)	(0.6)		(0.8)	(41)	(0.2)	(216)	(0.1)	(0.5)	(0.2)	(786)	(2278)	(0.1)	(695)	(0.02)	(1.1)	(34.3)
Liver	3.8	0.2	3.5	11.4	133	1.4	0.3	117	954	0.04	707	18.2	4.8	0.2	12000	9665	2.8	2140	0.1	14.9	131.6
	(0.4)	(0)	(0.7)	(8.2)	(24)	(0.6)	(0.1)	(46.7)	(52)	(0.04)	(18)	(5.2)	(0.9)	(0)	(424)	(1039)	(0.8)	(184)	(0.05)	(0.3)	(114)
Caribou (n = 2)																					
Kidney	7.0	3.1	2.0	38.4	400	<0.2	0.2	29.2	296	9.4	622	9.1	1.4	1.6	12555	14600	4.4	5940	0.3	12.0	125.5
	(5.9)	(0.5)	(1.4)	(33.4)	(71)		(0)	(6.3)	(93)	(6.7)	(43)	(0.2)	(0.4)	(1.8)	(7135)	(5374)	(1.1)	(1923)	(.03)	(0)	(10.6)
Muscle	3.8	0.4	2.0	<0.08	105	<0.2	<0.08	12.4	168	9.4	780	1.4	0.06	0.2	5025	10700	0.5	1300	0.1	13.8	116.5
	(0.2)	(0.1)	(1.4)		(21)			(2.8)	(37)	(7.4)	(50)	(0.2)	(.01)	(0)	(1011)	(1273)	(0)	(0)	(0.02)	(1.1)	(4.9)
Liver	3.2	0.7	<2	5.0	100	<0.2	0.2	66.3	614	8.3	419	11.0	3.2	0.2	6730	9190	0.6	1600	0.1	11.8	62.3
	(0.4)	(0.4)		(3.2)	(28)		(0)	(29.8)	(2)	(4.0)	(25)	(1.2)	(0.1)	(0.1)	(311)	(1287)	(0.1)	(438)	(0)	(0.1)	(2.8)

Table 3. Summary of radionuclide concentrations in moose and woodland caribou in the Sahtu. Data are given as average concentrations with standard deviations. The units are Bq·kg⁻¹ wet weight.

	Tissue	Dry Wt. %	Ash Wt. %	^{40}K	^{137}Cs	^{210}Pb	^{232}Th	^{226}Ra	^{241}Am	^{235}U	^{210}Po
Moose	muscle	23.3	1.20	198	2.77	<1.9	<0.63	<0.88	<0.19	<0.19	2.7
	(n=6)	(0.50)	(0.16)	(15)	(0.56)						(0.1)
	liver	29.5	1.35	165	1.07	3.01	<0.55	0.36	<0.17	<0.78	13.0
	(n=4)	(1.46)	(0.10)	(38)	(0.67)	(1.80)		(0.23)			(5.8)
	kidney	20.35	1.17	130	0.89	2.5	<0.39	<0.53	<0.12	<0.54	22.0
	(n=1)										
Caribou	muscle	26.4	1.15	188	25.4	<1.9	<0.60	0.40	<0.19	<0.91	7.4
	(n=2)	(1.46)	(1.10)	(3.84)	(2.19)			(0.17)			(0.3)
	liver	29.3	1.32	180	14.6	62.6	0.28	<0.65	<0.19	<0.84	230
	(n=2)	(1.59)	(0.03)	(27.2)	(3.95)	(13.1)	(0.03)				(38)

Table 4. Summarized data of the concentrations of organochlorine pesticides in moose and caribou. All concentrations are in ng·g⁻¹ wet weight. All other organic contaminants were below detection limits of approximately 0.1 ng·g⁻¹.

Sample	Tissue	Location	Wet Wt.	% Lipids	% Moisture	Total CBz	Total HCH	Total Chlor	Total DDT	Total PCBs
This study										
Moose (n=6)	fat	Fort Good Hope Tulita	0.96 (0.03)	66.87 (11.7)	29.42 (10.9)	2.67 (0.65)	0.58 (0.37)	0.18 (0.08)	0.36 (0.05)	0.20 (0.09)
Caribou (n=1)	fat	Tulita	0.97	88.33	9.75	26.18	3.32	0.13	0.93	0.53
Comparative data from Muir *et al.* (1989)										
Moose	raw meat	Fort Good Hope	–	1.0	–	0.2	1.4	0.5	1.2	11.2
Moose	raw liver	Fort Good Hope	–	3.5	–	1.8	20.2	0.8	0.4	21.2
Caribou	raw meat	Fort Good Hope	–	1.3	–	0.7	0.6	0.3	0.6	5.0
Caribou	raw meat	Fort Good Hope	–	1.0	–	0.5	0.9	0.3	0.7	4.0
Caribou	raw liver	Fort Good Hope	–	3.1	–	3.2	4.0	2.7	0.7	18.3

List of Symbols

Cbz	- total chlorobenzene (total of tetra-, penta- and hexachlorobenzenes)
HCH	- total hexachlorocyclohexane (alpha, beta and gamma isomers).
Chlor	- total chlordanes, includes all *cis*, *trans*, and metabolic products, although oxychlordane was the only chlordane detected.
DDT	- ΣDDT, all DDE, DDD and DDT isomers.
PCBs	- polychlorinated biphenyls, sum of 33 PCB congeners although CB 153, CB138, and CB180 were the only congeners detected.

Cadmium remains a major focus of environmental monitoring programs in the North and in southern Canada because of its ability to accumulate in the liver and kidney of herbivores, and its toxicity to people and animals. For this reason, Health Canada provides guidance, based on field surveys, on the amount of particular foods which can be safely consumed and, if necessary, issues consumption limits for specific food types. For example, a large survey in the Yukon by DIAND analysed the levels of metals in the livers and kidneys of caribou, moose, sheep, goat, beaver, porcupine and snowshoe hare (Gamberg 1996). It was recommended that 1 moose liver or kidney be consumed per year whereas there is no limit on the number of sheep and hare livers consumed. Because of big differences in the levels of cadmium between caribou herds, recommendations range from consuming 4 livers in the Tay herd to 16 in the Bonnet Plume. Although the levels of Cd in moose liver and kidney are slightly lower than those in the Yukon, a similar assessment should be conducted by Health Canada which includes dietary and other exposure data unique to the Sahtu Dene.

Radionuclides

The levels of radionuclides are low in both species. The most common radionuclide is ^{40}K, a natural radionuclide which is found in all living material. Although the concentration of ^{210}Po, a naturally-occurring decay product of ^{238}U (which is present in rocks throughout the Northwest Territories) is higher in the woodland caribou than the moose, the levels in both species are still lower than in barren ground caribou which routinely have levels of 400 to 500 $Bq \cdot kg^{-1}$ wet wt. in liver (Macdonald *et al.* 1996). The lower levels in the two woodland caribou, relative to barren ground caribou, probably reflects less lichen in the woodland caribou diet. Although the number of samples is very small, based on these data, there is no evidence of elevated local sources of naturally-occurring radiation. The concentration of the human-made radionuclide ^{137}Cs is also very low, which suggests that lichen, the major transport pathway to herbivores is relatively low in the woodland caribou diet.

Organochlorines

Organochlorines remain a major concern in the North because of their ability to accumulate to very high concentrations in animals with high fat levels and in long food chains. Organochlorines tend to be at much lower concentrations in terrestrial systems because of the short food chain (i.e. plant–moose–human or lichen–caribou–human). These conclusions are supported in the present study which showed very low levels of all organochlorine contaminants in fat in both moose and caribou fat. The data are summarized in Table 4 with data from a report by Muir *et al.* (1989) on meat and liver from moose and caribou taken near Fort Good Hope. Whereas the current study shows chlorobenzenes to be the major residues found (CBz:PCB>10), Muir *et al.* (1989) report PCBs to be the greater residues by about 10 times. Regardless of these differences, the low levels of all organochlorines in meat and internal organs indicates that exposure to these compounds is low for both people and animals.

CONCLUSIONS

Although the number of samples collected is small, this study indicates that the levels of most contaminants are low and there should be no concern by the people in the Sahtu about eating moose and caribou. The possible exception to this is the level of cadmium found in moose kidney, which is lower than the levels found in the Yukon but is high enough to warrant an assessment by Health Canada as to the need for consumption guidelines. This assessment should be conducted with regard to the diet and exposure factors which are unique to the Sahtu Dene. It is recommended that the number of samples should be increased to provide a better idea of the variability and the range of values present in the Sahtu.

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INVESTIGATING THE IMPORTANCE OF WATER CHEMISTRY ON MERCURY CONCENTRATION IN FISH FROM MACKENZIE RIVER BASIN LAKES

Project Leader: Glen Stephens, Contaminants Division, Department of Indian Affairs and Northern Development (DIAND), NWT Region

Project Team: Lyle Lockhart, Freshwater Institute, Department of Fisheries and Oceans (DFO), Winnipeg, MB; Fort Good Hope Renewable Resources Committee; Denendeh Resources Committee (tentative).

OBJECTIVES

1. To characterize the water chemistry of lakes with reported elevated concentrations of mercury in fish from the Mackenzie River Valley which were sampled as part of DFO's Fisheries Management Program.
2. To establish any relationships between basic lake water chemistry and mercury levels in fish which could be used as a technique to identify areas with potential contaminant problems in the Mackenzie River Valley.
3. To develop a potential method for advising people of possible problems for public consumption of fish from lakes in the Mackenzie River Valley.

DESCRIPTION

Since 1996, mercury analysis has been conducted by the Freshwater Institute on samples collected from numerous lakes in the Mackenzie River Valley (Sahtu and Deh Cho regions) that have been part of DFO's Fisheries Management Program. This program investigates fish populations in lakes that have been selected after extensive consultations with the various renewable resource committees. The results have indicated a surprising number of lakes with above consumption level concentrations of mercury in fish. This is a concern because these lakes were selected for their importance to the community for subsistence, commercial or tourist use.

While extensive biological data is collected during the surveys, very little limnological information is collected which could help explain the differences in the mercury concentrations between lakes. An initial investigative tool could be water chemistry. There is an extensive body of literature suggesting a relationship between water chemistry and mercury concentration in both the water and fish compartments of the environment (for example, Joslin *et al.* 1994, Bodaly 1993, Mierle and Ingram 1991, Cope *et al.* 1990, McMurtry *et al.* 1989). If a relationship could be discovered between mercury concentration in fish and water chemistry for lakes in the Mackenzie River Valley, it could help communities and renewable resource committees develop environmental management plans and also help in selecting lakes for future fish surveys.

ACTIVITIES IN 1998/1999

Consultation letters were sent out to various organizations within the Sahtu and Deh Cho regions explaining the project and asking for some initial input on lakes.

Using DFO's fish contaminant database and lakes identified by the communities or organizations, sixteen lakes were sampled (see Appendix A) in July and August for basic water chemistry. The samples were sent to Taiga Laboratory in Yellowknife for analysis (see Appendix B).

RESULTS

The data have been received from Tiaga Laboratory and are currently being interpreted. Initial indications are that basic water chemistry parameters are not significantly related to mercury concentrations in fish. A report is expected shortly and will be distributed to those organizations originally contacted.

Expected Project Completion Date: September 1999

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APPENDIX A: Lake Sampling Locations

LAKE	REGION	LOCATION
Cli Lake	Deh Cho	61° 59' N 123° 18' W
Little Doctor Lake	Deh Cho	61° 53' N 123° 16' W
Lac Belot	Sahtu	66° 55' N 126° 00' W
Colville Lake	Sahtu	67° 10' N 126° 00' W
Lac à Jacques	Sahtu	66° 05' N 127° 10' W
Turton Lake	Sahtu	65° 48' N 126° 55' W
Manuel Lake	Sahtu	66° 59' N 128° 55' W
Ekali Lake	Deh Cho	61° 17' N 120° 17' W
Gargan Lake	Deh Cho	61° 15' N 120° 23' W
Mahoney Lake	Sahtu	65° 30' N 125° 20' W
Kelly Lake	Sahtu	65° 25' N 126° 15' W
Sanguez Lake	Deh Cho	61° 15' N 120° 29' W
Sibbeston Lake	Deh Cho	61° 45' N 122° 45' W
Tsetso Lake	Deh Cho	61° 51' N 123° 01' W
Loon Lake	Sahtu	66° 40' N 128° 45' W
Rorey Lake	Sahtu	66° 53' N 128° 26' W

APPENDIX B: Water Sample Parameters

PARAMETERS

PHYSICALS
- pH
- Conductivity
- Turbidity
- Total Suspended Solids (NFR)
- Alkalinity
- Colour
- Dissolved Solids (FR)
- Chlorine

MAJOR IONS
- Chloride
- Sodium
- Calcium
- Hardness
- Reactive Silica
- Sulfate
- Potassium
- Magnesium
- Fluoride
- Sulfide

NUTRIENTS
- Dissolved Nitrogen
- Total Phosphorous
- Nitrite - Nitrogen
- Nitrate - Nitrogen
- Total Dissolved Phosphorous
- Total Organic Carbon (TOC)
- Total Inorganic Carbon (TIC)

METALS
- Total Mercury
- Total Arsenic (Hydride)
- ICP-MS -Cd, Cr, Co, Mn, Ni, Pb, Zn, Fe (AAS), Ag, Al, Ba, Be, Bi, Cs, Li, Mo, Sb, Se, Sr, Ti, U and V

TEMPORAL TRENDS OF ORGANOCHLORINES IN SOUTHEAST BAFFIN BELUGA AND HOLMAN RINGED SEAL

Project Leader: Gary A. Stern, Department of Fisheries and Oceans (DFO), Freshwater Institute (FWI), Winnipeg, MB and Richard F. Addison, Institute of Ocean Sciences (IOS), Sidney, BC.

Project Team: Krystyna Koczanski and Thor Holldorson, FWI, Winnipeg, MB; Michael Ikonomou, IOS, Sidney, BC; Terry Bidleman, Atmospheric Environment Service, Downsview, ON; Derek Muir, National Water Research Institute, Burlington, ON.

OBJECTIVES

1. To document the temporal trends of bioaccumulating substances such as PCBs, DDT, toxaphene (ΣCHB, chlorinated bornanes), coplanar PCBs, polychlorinated dibenzodioxins (PCDDs), dibenzofurans (PCDFs) and selected current use chemicals such as polychlorinated-*n*-alkanes (PCAs) and chlorinated and brominated diphenyl ethers (CDPEs/BDPEs) in Arctic marine ecosystems so as to determine whether contaminant levels in marine mammal tissues, and thus the exposure to people living in Arctic communities who consume them as part of their traditional diet, are increasing or decreasing with time.
2. To provide data on contaminant levels in marine mammal tissues as part of surveys of dietary contamination and for use by the Arctic Monitoring and Assessment Program (AMAP).

DESCRIPTION

Marine mammals are an important part of the traditional diets of people living in the Arctic coastal communities. These animals occupy high tropic levels in marine food webs and so accumulate relatively high concentrations of persistent organohalogen contaminants. Documentation of temporal trends in the extent of contamination of these compounds will contribute to an assessment of the risk incurred upon exposure to them. Because of their toxicological significance, analysis of new chemical contaminants (i.e. those not currently identified in the UN ECE LRTAP protocols) such as PCAs, CDPEs and BDPEs are essential and will provide a "baseline" against which future measurements can be compared.

ACTIVTIES IN 1998/99

1. Eastern Arctic Beluga

Blubber extracts from male southeast (SE) Baffin (Pangnirtung) beluga, previously analysed for PCBs and organochlorine contaminants (OCs) in the 1997/98 fiscal year, were analysed for coplanar PCBs. An additional eleven samples collected in 1997 and one each from 1986 and 1992, were also analysed for the whole range of contaminants (90 PCBs, 40 OCs, coplanar PCBs) in an effort to increase the statistical confidence of the results (only 6 sample were available from 1996). In total, 53 male animals (> 2 years of age) collected at four different time periods (1982, n=8; 1986, n=17; 1992, n=11; 1996/97, n=17) covering a 15 year time span were analysed. Some previously run samples were reanalysed, and in some cases the results verified using GC/MS, in an effort to try and eliminate some of the observed variations in the results (e.g. PCBs, DDT and its degradation products). As part of the 'New Chemicals proposal' (Bidleman, Muir and Stern), selected samples were analysed for CDPEs and BDPEs. Analysis of the eleven 1997 samples for PCAs has not yet been completed.

Sample collection

Beluga blubber samples from SE Baffin Island (Pangnirtung) animals, collected in the years 1982-1997 as part of a whale sampling program conducted by DFO and funded partly by the Nunavut implementation fund (NIF) and the Nunavut Wildlife Management Board (NWMB), were available for analysis from the archive maintained at the FWI.

Methods

Major OCs: Samples of beluga blubber were analysed for 130 individual organochlorine contaminants (90 PCB congeners and 40 other OC pesticides) as described by Muir *et al.* (1990). In Brief, 2 g of each blubber sample was combined with anhydrous sodium sulfate (heated at 600°C) for 16 hours prior to use. The mixture was then extracted twice with 50 mL of hexane using a ball mill, centrifuging and decanting the hexane between extractions. Surrogate recovery standards of CB30 and octachloronaphthalene (OCN) were added prior to extraction. Extractable lipids were determined gravimetrically on one tenth of the extract. A portion of the extract equivalent to approximately 100 mg was then separated into three fractions of increasing polarity on a Florisil column (8 g, 1.2% H_2O deactivated). The first fraction was eluted with hexane and contained PCBs, *p,p'*-DDE, chlorobenzenes, mirex, and a small portion of CHBs (toxaphene), most notably T2/B8-1413 (Stern *et al.* 1992, Andrews and Vetter 1995). Fraction two was eluted with hexane:DCM (85:15) and contained HCHs, chlordanes, and the remainder of the DDT and CHB congeners. The final fraction was eluted with a 1:1 mixture of hexane:DCM. Each of the three fractions were then analysed by high resolution gas chromatography with electron capture detection (HRGC/ECD) using a 60 m x 0.25 mm DB-5 capillary column (0.25 µm film thickness) with hydrogen carrier gas. Total PCB (ΣPCB) corresponds to the sum of all congeners. Total chlordane (ΣCHL) to the sum of all chlordane related compounds and DDT (ΣDDT) to the sum of *p,p'*-DDE, *o,p'*-DDE, *p,p'*-DDD, *o,p'*-DDD, *p,p'*-DDT and *o,p'*-DDT. Toxaphene (ΣCHB) was quantified using a single response factor based on 27 peaks in the technical mixture. Approximately 75-80% of ΣCHB in beluga blubber is ascribed to two individual congeners, an octa- and nonachlorobornane, referred to as T2 (Parlar#26, B8-1413) and T12 (Parlar#50, B9-1679) (Stern *et al.* 1992, Andrews and Vetter 1995).

BDPEs and CDPEs: Analysis of BDPEs and CDPEs were conducted at the DFO Regional Contaminants Laboratory, located at IOS and directed by Dr. M.G. Ikonomou. The analytical methods are in place at IOS and data on the performance of the methods and preliminary measurements from a number of environmental samples were presented at DIOXIN-99 (Sergeant *et al.* 1998).

Quality assurance

Major OCs: The average recovery for both internal standards, PCB 30 and OCN, was 96%. The cod liver oil standard reference material (SRM-1588) from NIST (Gaithersburg, VA) was used as a laboratory control sample for major OC pesticides and PCB congeners and was run with every second set of samples (8 samples per set). One duplicate sample was also run with every second set of samples and blanks were run approximately every ten samples to check contamination of reagents and glassware.

BDPEs and CDPEs: The overall analytical methods have been tested for accuracy and precision by spiking and processing environmental matrices of interest. Percent recoveries for all target analytes varied between 75% and 110%. For the BDPEs analysis, there are 23 native congeners available and 5 surrogate internal standards. For the CDPEs analysis, there are 18 native congeners available and 6 surrogate internal standards. Samples will be processed in batches of twelve consisting of a procedural blank, a spiked reference sample and nine real samples out of which one will be processed in duplicate. All samples will be spiked with the entire suite of the surrogate internal standards and the percent recoveries will be monitored. Acceptable range for the surrogate recoveries will be between 60 and 115% and all the analyte concentrations will be corrected for surrogate recovery. All samples will be analysed by HRGC/HRMS and the criteria for identification and quantification will be parallel to those used for dioxins/furans analysis as described in the EPS report 1/RM/19 (February 1992).

Statistical analysis

All univariate analyses were performed with lipid normalized $\log_{10}$ transformed data to adjust for skewness. ANCOVA was used to asses the effects of year-to-year collections (temporal trends), age of the animals and age*year interactions (homogeneity of slope between age and [OC]) using the model [OC] = year age age*year, where [OC] = log concentration of each organochlorine group. Differences between collection years were examined with paired comparisons of age-adjusted least squared mean concentrations (SAS Institute 1989-1996). Only results for animals older than two years of age were included in the analysis of covariance because of the large variations in concentrations seen in younger animals (Stern *et al.* 1994, Muir *et al.* 1996).

RESULTS

Major OCs

Figure 1 (top) shows the temporal trends of the lipid normalized, age-adjusted least square mean concentrations of individual HCH isomers and ΣHCH. Years in which statistically significant differences ($p <$ 0.05) were observed have been indicated on the figure and are also listed in Table 1. ΣHCH and α-HCH concentrations declined by approximately 1.3- and 1.4-fold, respectively, over the fifteen year interval from 1982 to 1997 while no significant differences were observed for the β- and γ-HCH isomers. The decreasing trend in ΣHCH and α-HCH concentrations is consistent with the 9-fold decline in Arctic airborne concentrations over the 14 year period from 1979-1993 and with the significant but much smaller reduction (3% per year) of ΣHCH in surface seawater (Jantunen and Bidleman 1995, Bidleman *el al.* 1995, AMAP 1998). As a whole, ΣDDT concentrations did not change over this 15-year time interval. Individually, however, a 2.2-fold decline and a 1.3-fold increase in the least square mean concentration of *p,p'*-DDT and its metabolite *p,p'*-DDE, respectively, was observed. These changes translate into a significant increase in the *p,p'*-DDE/EDDT ratio from 0.37-0.48 and suggests "old" rather than recent DDT inputs (Figure 1, bottom). A 1.6-fold increase in the least square mean concentration of *o,p'*-DDD was observed while no significant differences were detected for *o,p'*-DDE or *p,p'*- DDD. A significant age-year interaction (age*year)

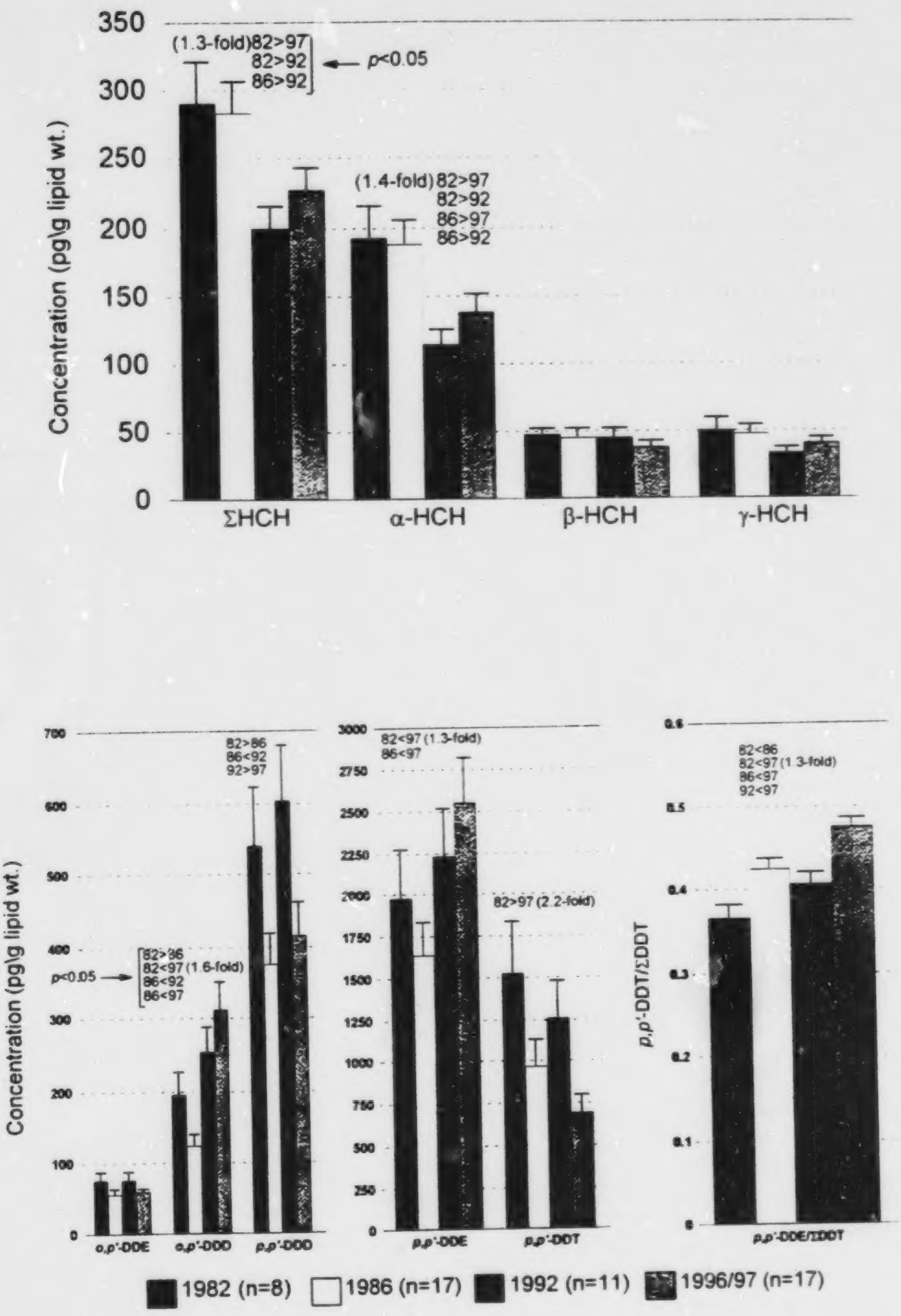

Figure 1. Temporal trends of lipid normalized (age-adjusted least square mean) concentrations of ΣHCH, α–, β– and γ– HCH (top) and *o,p'*-DDE, *o,p'*-DDD, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT and *p,p'*-DDE/ΣDDT (bottom) in male Pangnirtung beluga blubber samples.

Table 1. Summary of ANOVA results used to assess the affects of year-to-year collections (temporal trends), age of the animals and age*year interactions (homogeneity of the slope between age and [OC]) of OCs in male Pangnirtung beluga blubber samples (Only results from animals > 2 years were included).

	Year (Pr)	Age (Pr)	Age*year (Pr)	R^2 (model)	Year[a]
ΣHCH	0.0151	0.1877	0.8333	0.24	82>92, 97; 86>92
α-HCH	0.0033	0.1508	0.7607	0.28	82>92, 97; 86>92, 97
β-HCH	0.5510	0.5832	0.5487	0.09	–
γ-HCH	0.1805	0.4555	0.8662	0.12	82>92
ΣDDT	0.0993	0.0001	0.0666	0.39	82>86; 86<92, 97
o,p'-DDE	0.0870	0.0002	0.7841	0.47	–
p,p'-DDE	0.0779	0.0001	0.1581	0.39	97>82, 86
o,p'-DDD	0.0001	0.0001	0.3783	0.67	82>86, 82<97; 86<92, 97
p,p'-DDD	0.0201	0.0014	0.4997	0.43	82>86; 86<92; 92>97
o,p'-DDT	0.0055	0.0001	0.0158	0.66	–
p,p'-DDT	0.0039	0.0400	0.2143	0.38	82>97; 92>97
Ratio[b]	0.0001	0.2152	0.2583	0.47	82<86, 97; 97>86, 92
ΣECHL	0.0208	0.0005	0.1512	0.39	82<97; 86<92, 97
c-CHL	0.2348	0.3390	0.9666	0.15	82>97, 92
t-CHL	0.0001	0.0001	0.8526	0.53	82<97; 82>86; 86<92, 97
c-Nona	0.0001	0.0031	0.1142	0.47	82>86; 86<92, 97
t-Nona	0.0002	0.0001	0.1905	0.56	82<92, 97; 86<92, 97
Oxychlor	0.2525	0.5034	0.3370	0.09	–
ΣCBz	0.0001	0.0030	0.3939	0.49	82>92; 97>86, 92
ΣCHB	0.6091	0.0004	0.8637	0.27	–
Dieldrin	0.0013	0.0101	0.9461	0.37	82>92, 97; 86>92; 92<97
ΣPCB	0.0001	0.0001	0.0214	0.75	–
Mono/di-CB	0.0001	0.6158	0.0113	0.69	–
Tri-CB	0.0003	0.0001	0.0096	0.58	–
Tetra-CB	0.0003	0.0001	0.0302	0.57	–
Penta-CB	0.0001	0.0001	0.0072	0.72	–
Hexa-CB	0.0001	0.0001	0.2112	0.73	82>86, 92; 86<92, 97; 92<97
Hepta-CB	0.0001	0.0001	0.0986	0.70	82>86, 97; 86<92, 97
Octa-CB	0.0340	0.0001	0.1617	0.53	82>86
Nona-CB	0.0140	0.0051	0.7773	0.31	82>86; 86<92
Tetra-*n*PCB	0.0275	0.0802	0.0232	0.22	82>92, 97; 86>92, 97
CB77	0.5462	0.0274	0.4087	0.13	–
CB79	0.0881	0.1064	0.1729	0.17	82>92, 97
CB80	0.0008	0.6856	0.5787	0.29	82>92, 97; 86>92, 97
CB81	0.0534	0.3680	0.2375	0.16	82>97
CB126	0.0768	0.7323	0.0820	0.14	82>92, 97
CB169	0.0683	0.3517	0.9769	0.15	82>92, 97

[a] Significant differences in least square mean concentrations of individual OCs and groups for all four collection years ($p<0.05$);

[b] *p,p'*-DDE /ΣDDT (ratio value. were not log transformed). Tetra-*n*PCB = ΣCB77, 78, 79, 80, 81

was observed for *o,p'*-DDT and as a result, ANCOVA could not be used to correct for the observed age effects (Table 1). Two of the most abundant congeners in technical chlordane, *cis*- and *trans*-nonachlor, increased in concentration by 1.4- and 1.7-fold, respectively, from 1982-1997 while only *cis*-CHL showed any significant decline. Overall, a 1.2-fold increase in the least square mean concentrations of ΣCHL was observed (Figure 2, top). Oxychlordane, the principal metabolite of *cis*- and *trans*-chlordane, second only to *trans*-nonachlor as the most abundant chlordane-related residue in the SE Baffin beluga blubber, did not change significantly over this 15 year period. Though its use has been banned in Canada and the United States since the late 1980s, continued use of chlordane in countries such as Mexico, which until very recently was importing over 45 tons of chlordane annually from the United States (where it is still legal to manufacture), may be one of the contributing factors giving rise to the observed increase. Figure 2 (bottom) shows the temporal trends of the lipid normalized, age-adjusted least square mean concentrations for the hexa- and hepta-CB homologue groups, dieldrin and ΣCHB (toxaphene). Over the 15-year period from 1982 to 1997, a 1.3- and 1.4-fold decline in Hepta-CB and dieldrin levels, respectively, were observed. Although there were significant differences in age- adjusted least square mean concentrations of the Hexa-CB level, no clear trend was evident. No significant differences were observed for toxaphene. For the mono-/di- to penta-CBs, age-year interaction (age*year) were significant ($p>0.05$) and as a result, ANCOVA could not be used to correct for the observed

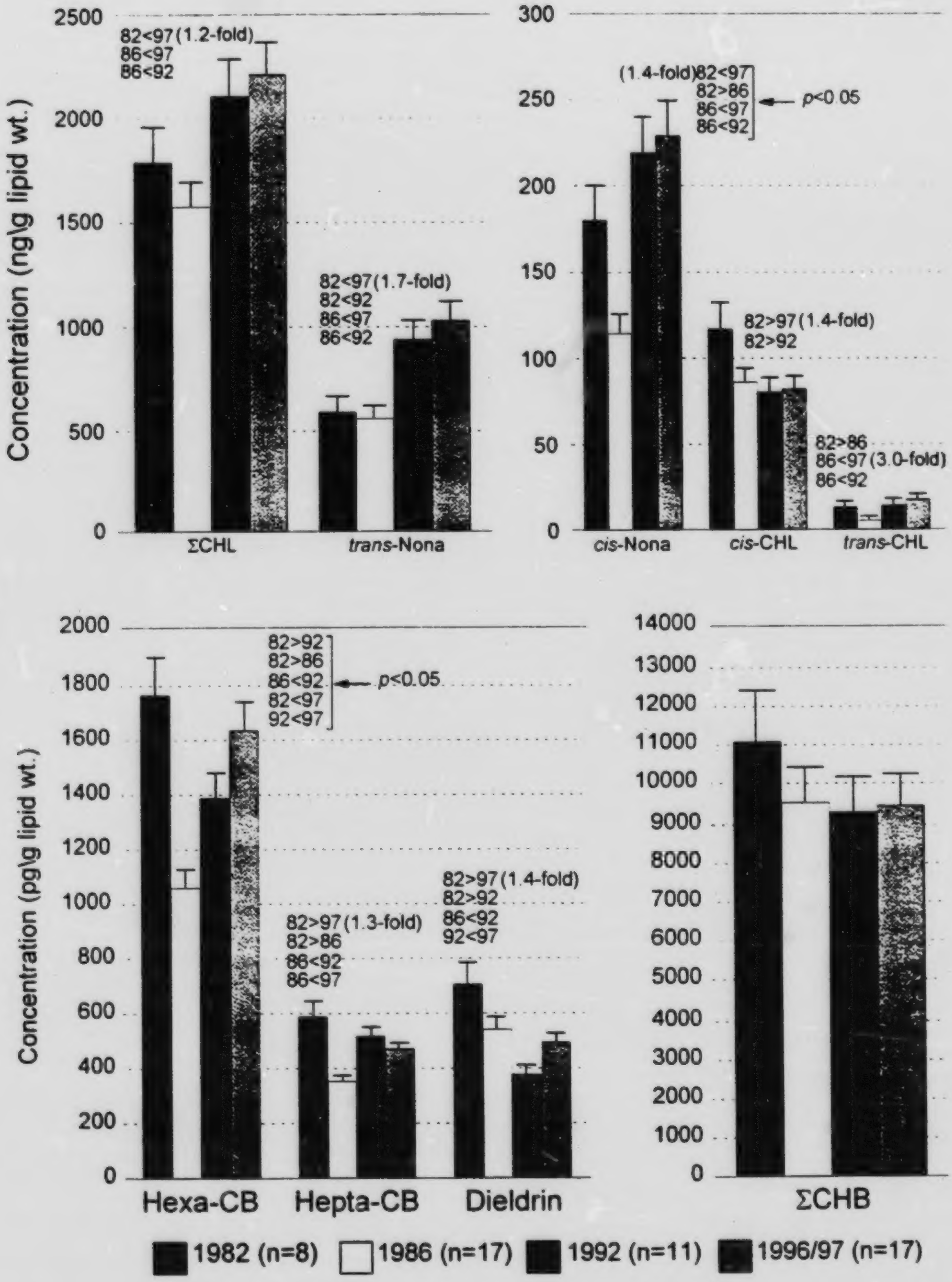

Figure 2. Temporal trends of lipid normalized (age-adjusted least square mean) concentrations of ΣHCL, *cis-*, *trans*-Nona, *cis-*, *trans*-CHL (top) and hexa-, hepta-CB, dieldrin and ΣCHB(bottom) in male Pangnirtung beluga blubber samples.

age effects (Table 1).

Coplanar PCBs

Information on the levels of the toxic coplanar (or non-*ortho* substituted, *n*PCB) PCBs and other planar OCs in marine mammals is limited in comparison to other OCs, however, where coplanar PCBs have been measured along with PCDD/Fs, PCNs and CDPEs, calculations of TCDD TEQs show that the coplanar PCBs, especially CB126, account for most of the TEQs (Jensen *et al.* 1997, AMAP 1998). Temporal trends of the lipid normalized, age-adjusted least square mean concentrations of *n*PCBs (CB77, 79, 80, 81, 126, 169 and ΣTeCB) are shown in Figure 3. With the exception of CB77, over the 15-year period from 1982 to 1997, significant declines ranging from 1.7-fold for CB80 to 2.8-fold for CB126, were observed. Accordingly, *n*PCB TEQs (CB77, 126 and 169) have declined from 16.02 to 6.07 pg·g^{-1} (2.6-fold) over the same time period.

DPEs/BDPEs: The similarity in molecular structure of the CDPEs and BDPEs, with PCBs, gives rise to great concern. Because of their known persistence and ability to bioaccumulate (Pijnenburg *et al.* 1995, de Boer *et al.* 1998, Humppi and Keinola 1985) and their continued release into the environment (Sellström and Jansson 1995, Sellström 1996, Zitko 1993, Watanabe and Tatssukawa 1989, Paasivirta *et al.* 1986, Firestone *et al.* 1972), large quantities of the BDPEs (flame retardent) and CDPEs (by-products in the manufacturing process of chlorophenols) produced could eventually reach the Arctic marine environment where they then could pose an increasing risk to aquatic biota and to the people living in Arctic communities (Safe 1992, Howie *et al.* 1990). In this study, blubber extracts from a selected number of older animals (>17 yr) were analysed for BDPEs (Table 2) and CDPEs (Table 3). Mean concentrations of ΣBDPE and ΣCDPE in the Pangnirtung beluga were 10.24 ± 2.30 and 60.44 ± 9.12 ng·g^{-1}, respectively. As observed in blubber samples from the Kimmirut beluga (Muir *et al.* 1998), the Br_4-DPEs were predominant, in particular the 2,3',4',6-BDPE congener which represents ~80% of the total. Four-fold higher ΣBDPE levels were observed in the Pangnirtung beluga, but this can almost certainly be attributed to the fact that the mean age of the Pangnirtung animals was 20.2 years relative to 6.3 years for the Kimmirut animals. ΣBDPE concentrations were about 6-fold lower than ΣCDPE concentrations which, in turn, were about 80-fold lower than ΣPCBs.

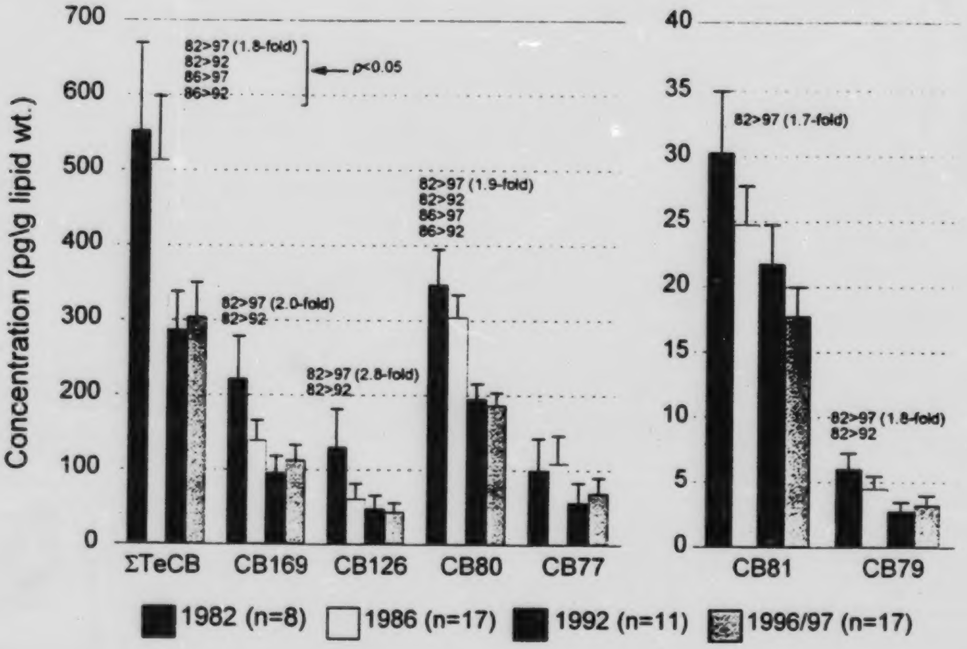

Figure 3. Temporal trends of lipid normalized (age-adjusted least square mean) concentrations of coplanar PCBs (*n*PCB) in male Pangnirtung beluga blubber samples.

Table 2. Brominated diphenyl ethers (ng·g^{-1}) in blubber samples from five male Pangnirtung beluga (age>17 yr).

Sample	Year	Br_3-DPE	Br_4-DPE*	Br_5-DPE	Br_6-DPE	Br_7-DPE	ΣBDPE
B-92-06	1992	0.713	6.52	0.715	0.244	0.006	**8.20**
B-92-10	1992	0.807	8.96	1.04	0.410	–	**11.22**
B-92-13	1992	0.932	8.85	1.15	0.020	–	**10.95**
B-95-59	1996	0.663	5.41	0.628	0.027	0.130	**6.85**
B-95-544	1996	0.887	9.69	1.20	0.125	0.046	**11.95**

*In each sample the 2,3',4',6-BDPE congener corresponds to ~80% of tetra-BDE

Table 3. Chlorinated diphenyl ethers (CDPEs) and ΣPCB concentrations (ng·g^{-1}) in blubber samples from four male Pangnirtung beluga (age>17 yr).

Sample	Year	Cl -DPE	Cl -DPE	Cl -DPE	Cl -DPE	Cl -DPE	Cl -DPE	ΣCDPE	ΣPCBs
B-92-06	1992	0.363	4.49	8.15	39.0	7.59	2.17	**61.76**	6596
B-92-10	1992	0.201	2.53	6.25	40.0	8.75	2.77	**60.50**	6037
B-92-13	1992	0.244	2.71	4.63	47.0	11.0	3.95	**69.53**	5981
B-95-544	1996	0.703	4.61	8.19	33.0	3.51	1.29	**51.30**	4965

Table 4. PCDD/F concentrations (pg·g^{-1} wet weight (wt.)) in blubber from Holman ringed seals sampled in 1981, 1991 and 1996. Data given as mean ± standard deviation (number of samples in which residues were detected); 9 samples were analysed in each year (from each sex in 1996). ND = not detected.

Compound	1981 (male)	1991 (male)	1996 (male)	1996 (female)
2,3,7,8-TCDD	5.80 ± 3.78 (9)	3.09 ± 4.51 (9)	3.08 ± 3.30 (9)	1.29 ± 0.53 (8)
1,2,3,7,8-PeCDD	0.56 ± 0.35 (6)	0.48 ± 0.40 (8)	0.94 ± 0.58 (7)	0.69 ± 0.37 (5)
1,2,3,4,7,8-HxCDD	ND	ND	0.29 ± 0.17 (2)	0.43 (1)
1,2,3,6,7,8-HxCDD	0.86 ± 0.36 (6)	0.60 ± 0.20 (9)	ND	ND
1,2,3,7,8,9-HxCDD	0.14 ± 0.03 (3)	0.15 ± 0.04 (5)	ND	ND
1,2,3,4,6,7,8-HpCDD	0.70 ± 0.40 (7)	0.14 ± 0.08 (2)	ND	ND
OCDD	6.74 ± 10.3 (7)	0.73 ± 0.44 (6)	ND	ND
2,3,7,8-TCDF	3.67 ± 1.13 (9)	2.60 ± 1.18 (9)	2.93 ± 0.73 (9)	3.19 ± 1.36 (9)
1,2,3,7,8-PeCDF	0.28 ± 0.22 (4)	0.24 ± 0.14 (5)	0.68 ± 0.10 (3)	0.48 (1)
2,3,4,7,8-PeCDF	0.31 ± 0.12 (5)	0.25 ± 0.10 (6)	0.53 (1)	0.43 (1)
1,2,3,4,7,8-HxCDF	0.95 ± 0.06 (2)	ND	0.46 ± 0.16 (2)	0.48 ± 0.22 (4)
1,2,3,6,7,8-HxCDF	0.06 (1)	ND	0.18 (1)	0.32 (1)
2,3,4,6,7,8-HxCDF	ND	ND	ND	ND
1,2,3,7,8,9-HxCDF	ND	ND	ND	ND
1,2,3,4,6,7,8-HpCDF	0.14 ± 0.07 (4)	0.34 (1)	ND	ND
1,2,3,4,7,8,9-HpCDF	ND	ND	ND	ND
OCDF	0.80 (1)	ND	ND	ND

Table 5. Concentrations ($pg \cdot g^{-1}$ wet wt.) of *n*PCBs (CB35, 37, 77 and 127) and *m*PCBs (CB61, 68, 70, 72 and 124) in blubber from Holman ringed seals sampled in 1981, 1991 and 1996. Data as mean ± s.d. (no. of samples in which residues were detected); 7 samples were analysed in 1981, 9 in 1991 and 9 from each sex in 1996. Data in the same row followed by a different letter differ significantly by *t*-test ($P < 0.05$). ND = not detected.

Compound	1981 (male)	1991 (male)	1996 (male)	1996 (female)
CB35	2.17 ± 1.49 (6) a	0.29 ± 0.06 (7) b	ND	ND
CB37	49.0 ± 47.9 (7) a	4.37 ± 1.07 (9) b	ND	ND
CB77	30.1 ± 10.2 (7) a	17.8 ± 7.79 (9) b	ND	ND
CB127	384 ± 222(7) a	266 ± 160 (9) a	73.9 (1)	3.60 ± 3.30 (4) b
CB61	22.8 ± 9.15 (7) a	13.7 ± 3.10 (9) b	15.3 ± 7.60 (9) ab	–
CB68	57.1 ± 50.9 (7) ab	18.6 ± 17.7 (9) b	72.1 ± 37.8 (9) a	–
CB70	4.66 ± 1.89 (7) a	2.11 ± 0.88 (9) b	1.68 ± 0.54 (9) b	–
CB72	50.2 ± 20.2 (7) a	21.6 ± 10.4 (9) b	38.4 ± 20.4 (9) a	–
CB124	183 ± 84.7 (7) a	98.3 ± 52.6 (9) b	50.6 ± 18.4 (9) c	–

2. Holman ringed seal

Archived samples of ringed seal blubber collected from subsistence hunts at Holman, NWT, in 1981, 1991 and 1996 have been analysed for polychlorinated dibenzodioxins (PCDD), dibenzofurans (PCDF) and for non-*ortho* and mono-*ortho* chlorobiphenyls (*n*PCB and *m*PCB), using methods described in detail by Addison *et al.* (1999). The 1996 Holman ringed seal samples have been analysed for major OC groups such as DDT, HCH, CBz and chlordane, but the results have not yet been evaluated.

Results

PCDD/F concentrations were very low and close to the detection limits for the analytical method; in many cases, residues were detected only sporadically (Table 4). Concentrations were low compared to samples from, for example, BC harbour seals (Addison *et al.* 1996) and were comparable with concentrations in Sable Island grey seals, which are remote from any local source of PCDD/F (Addison *et al.* 1999).

Temporal trends: PCDD/F concentrations in the Holman seals showed no clear decline between 1981 and 1996. This is partly due to the fact that concentrations were variable and close to detection limits, thus complicating statistical comparisons. However, taken together, the data suggest that they reflect a general Arctic "background" contamination by these compounds (Table 4). Concentrations listed in Table 4 are similar to those described by Norstrom *et al.* (1990) for Beaufort Sea ringed seal blubber, where comparisons can be made (2,3,7,8-TCDD, 2,3,7,8-TCDF and 1,2,3,6,7,8-HxCDD).

*n*PCBs were also present at low concentrations and showed high variance. Eighteen *n*PCBs (CB11, 12, 13, 14, 15, 35, 36, 37, 38, 39, 77, 78, 79, 80, 81, 126, 127 and 169) were measured. Most of these showed no changes over the sampling interval ($P > 0.05$ by *t*-test for year-to-year comparisons) but three (CB35, 37 and 77) showed some decline (Table 5). Twenty-three *m*PCBs were measured (CB55, 58, 60, 61, 66, 68, 70, 72, 105, 106, 108, 111, 114, 118, 122, 123, 124, 156, 157, 159, 162, 167 and 189). Several of these (listed in Table 5), usually the less chlorinated compounds, showed some decline over the sampling interval, while one (CB68) appeared to increase slightly in concentration between 1981 and 1996. However, although some changes were noted in concentrations of specific congeners, total *m*PCB concentrations did not change significantly between 1981 and 1996 in these male animals. This conclusion is consistent with independent analyses of trends in PCB estimated as Aroclor 1254 which showed no decline between 1981 and 1991 (Addison and Smith 1998).

Variation with sex: In seal blubber, most OCs are present at lower concentrations in females than in males, since females can clear residues through lactation. In the 1996 sampling, both male and female samples were analysed for PCDD/F and for *n* and *m*PCBs. Table 6 shows that several *m*PCB congeners were present at significantly lower concentrations ($P < 0.05$, *t*-test) in female than in male animals, and that the sum of *m*PCBs was almost significantly different between the sexes ($P = 0.0505$, *t*-test). In contrast, none of the PCDD/F congeners differed significantly between the sexes (Table 6). Since other studies have shown that PCDD/F are handled similarly to other OCs in other species of seal (Addison *et al.* 1999), we attribute this (apparent) absence of a sex difference to the fact that PCDD/F congeners were measured close to detection limits

CONCLUSIONS

The availability of archived beluga blubber samples, combined with the fact that all the analyses (samples collected from animals over the 15-year period from 1982-1997) were conducted by the same analyst using the same methodology and instrumentation makes this study unique. Significant declines were observed for

Table 6. Concentrations (pg·g^{-1}, wet wt.) of *m*PCBs in blubber of male and female Holman ringed seals sampled in 1996. Data as mean ± s.d. (no. of samples in which residues were detected); probability (*P*) of a difference between sexes being significant by *t*-test is shown. ND = not detected.

Compound	Male	Female	(*P*)
CB60	3020 ± 1070 (9)	2500 ± 1360 (9)	0.38
CB61	15300 ± 7600 (9)	11800 ± 4200 (9)	0.25
CB66	13500 ± 8570 (9)	7200 ± 6300 (9)	0.10
CB68	72.1 ± 37.8 (6)	141 ± 93.5 (4)	0.14
CB70	1680 ± 536 (9)	2020 ± 799 (9)	0.31
CB72	38.4 ± 20.4 (9)	46.3 ± 31.8 (7)	0.56
CB105	21100 ± 10800 (9)	11700 ± 5070 (9)	<0.05
CB108	2860 ± 1400 (9)	2100 ± 1840 (9)	0.34
CB111	397 ± 748 (9)	79.7 ± 39.8 (9)	0.32
CB114	1600 ± 812 (9)	945 ± 389	< 0.05
CB118	58200 ± 28900 (9)	33800 ± 17500 (9)	< 0.05
CB123	809 ± 246 (5)	686 ± 620 (4)	0.69
CB124	50.6 ± 18.4 (9)	60.7 ± 27.2 (8)	0.38
CB156	4240 ± 2400 (9)	2270 ± 863 (9)	< 0.05
CB157	1420 ± 767 (9)	828 ± 339 (9)	0.05
CB159	26.1 ± 28.6 (3)	ND	
CB162	253 ± 140 (9)	187 ± 170 (8)	0.39
CB167	1170 ± 890 (9)	714 ± 823 (9)	0.27
CB169	137 ± 81.7 (9)	70.4 ± 23.7 (8)	< 0.05
Σ*m*PCBs	**125000 ± 57200 (9)**	**76600 ± 39100 (9)**	**0.05**

ΣHCH and α-HCH, which is consistent with the downturn of the Arctic airborne levels. Although no change in ΣDDT concentration were observed, *p,p'*- DDT levels declined by 54% while *p,p'*-DDE levels increased by 29%. A significant increase in *p,p'*-DDE/ΣDDE was also observed suggesting "old" rather than recent DDT inputs. Levels of ΣCHL and two of the most abundant congeners in the technical chlordane mixture seem to be on the rise and dieldrin and hexa-CB levels are declining. No significant differences were observed for toxaphene. With the exception of CB77, significant declines were observed for coplanar PCBs which is paralleled by a similar decrease in *n*PCB TEQs. Mean ΣBDPE concentrations were about 6-fold lower than ΣCDPE concentrations which, in turn, were about 80-fold lower than ΣPCBs.

Future work will involve expanding the analysis of BDPEs and CDPEs to all 53 male Pangnirtung beluga blubber samples and to screen a selected number of samples for polybrominated biphenyls (PBBs). Based on a sampling frequency of every 4 to 5 years, the next collection of samples should take place in the 2002/2003 fiscal year.

PCDD/F were present only at very low concentrations in Holman ringed seal blubber, and showed no clear trend between 1981 and 1996. No difference in PCDD/F concentrations between male and female samples was observed (1996 samples only) in contrast to the behaviour of other OCs such as PCB congeners, which are usually present at lower concentrations in females than in males. *n- and m*PCBs showed only small or non-significant changes between 1981 and 1996, consistent with earlier analyses of PCBs.

Results of the work will be provided to Health Canada.

Expected Project Completion Date: Temporal trend studies are long-term propositions and thus this project should continue well into the new millennium.

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CONTAMINANTS IN ARCTIC SEA DUCKS

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OBJECTIVES

1. To examine heavy metal levels in eider tissues at different localities in the Arctic and to assess whether geographic variation occurs in levels of these contaminants and whether there are sublethal health effects in the birds associated with exposure to these contaminants.
2. To determine whether these contaminants in eider tissues may pose a risk to people who eat them, to pinpoint areas where the risk (if any) may be highest, to postulate potential sources of these contami-nants and to assess whether they may be contributing to the apparent population declines in these species.

DESCRIPTION

It is believed that for duck species in the Arctic, contaminants exposure occurs mainly during the winter in non-arctic environments (Henny *et al.* 1991). Trace elements, including mercury (Hg), cadmium (Cd) and selenium (Se) in the livers and kidneys of certain sea duck species from Alaska are quite high and, depending on their relative importance in a consumer's overall diet, may pose a risk to people who eat these tissues (Henny *et al.* 1995). For example, liver mercury in sea ducks from Alaska often exceeds 2 $\mu g \cdot g^{-1}$ dry weight (dry wt.) while cadmium and selenium often exceed 20 $\mu g \cdot g^{-1}$ dry wt. For mercury, consumption of as little as 46 g of liver containing 2 $\mu g \cdot g^{-1}$ dry wt. (0.6 $\mu g \cdot g^{-1}$ wet wt.) would equal the Tolerable Daily Intake (TDI) of mercury for a 60 kg person. In the case of cadmium, a 60 kg person's TDI would be met by consuming only 10 g of tissue containing Cd at 20 $\mu g \cdot g^{-1}$ dry wt. Mercury, cadmium and selenium are quite low in breast muscle of eiders from the Canadian Arctic (B. Braune, *pers. comm.*), however they do not normally concentrate in this tissue. Rather, they occur in their highest concentrations in liver and kidney, organs that are eaten by residents of several arctic communities. Concentrations of these contaminants in liver and kidney of sea ducks in the Canadian Arctic are not known. There is also some concern for the health of the ducks with high levels of these contaminants, particularly whether the apparent population declines these species have been experiencing (Turner *et al.* 1996) may be attributable to high levels of trace element contamination.

In the western Arctic, approximately 20,000 king eiders and 2500 common eiders are harvested annually (Turner *et al.* 1996). In the Inuvialuit Settlement Region, 2000 – 5000 eiders are harvested each year (Fabijan *et al.* 1997). In the eastern Arctic, it is estimated that approximately 14,000 eiders are harvested per year with the communities of Pangnirtung, Cape Dorset, Iqaluit and Lake Harbour harvesting the bulk of the birds (Turner *et al.* 1996). It is likely that some families in these communities are eating many eider meals each year. These meals include liver and kidneys, organs in which mercury, cadmium and selenium accumulate.

Population declines in arctic eiders have been documented. The number of king and Pacific common eiders migrating past Point Barrow, Alaska during spring migration apparently declined by more than 50% between 1976 and 1994 (Turner 1996, Suydam *et al.* 1997). Some researchers have estimated declines in these species of up to 75% (summarized by Turner *et al.* 1996). Recent information from the Rasmussen Basin indicating that king eider populations have declined by around 75% (Gratto-Trevor *et al.* 1998) supports the above estimates. In the eastern Arctic, the population status of king and common eiders is unknown, although it is possible that the king eiders from the Rasmussen Basin referred to above are of eastern Arctic origin. The problem of sea duck decline is not restricted to eiders. In Alaska, scoter populations declined 30% between 1957 and 1993 (cited in Henny *et al.* 1995). In Canada, such estimates are unavailable. Declines of scoters in the western Pacific rim have also been alluded to by Goudie *et al.* (1994). The reasons for sea duck population declines are unclear. Over-hunting, oil spills, increased nest predation, contaminants and nutritional or physiological factors have been cited as possible factors (Environment Canada 1996; Turner *et al.* 1996).

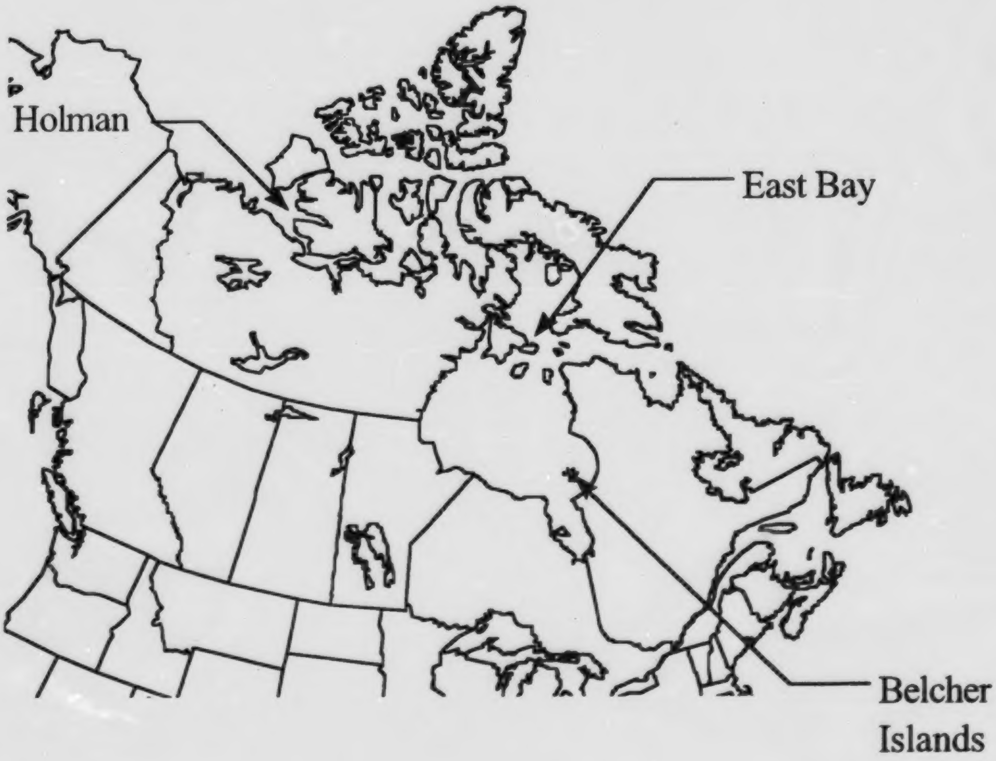

Figure 1. Map showing locations of eider collections.

While overhunting is a major concern for king and common eiders, other factors are probably also important in regulating populations of these species (Turner *et al.* 1996).

Worldwide, there is growing suspicion that population declines or massive die-offs of several species are related indirectly to pollution. The growing list includes several species of birds and marine mammals, for example, striped dolphins from the Mediterranean Sea, bottlenose dolphins from the eastern seaboard of the USA, harbour seals from the North and Baltic Seas, and bald eagles on the Great Lakes (Colborn *et al.* 1996). The central tenet of this study is that contaminants could be interacting with other physiological stressors in the environment to exert population level effects on eiders in the Canadian Arctic. Henny *et al.* (1995) have speculated that exposure of Alaskan sea ducks to high levels of cadmium, selenium and mercury may be contributing to these declines. However, toxicological effects in sea ducks exposed to high levels of heavy metals have not been documented.

Distinct populations of eiders are recognized in the Canadian Arctic. Western Arctic populations of king and common eiders winter in the Bering and Chukchi Seas while eastern Arctic eiders winter along the Atlantic coast and off the coast of Greenland while a subpopulation of common eiders winters in Hudson Bay. Contaminants exposure, which is thought to occur primarily during winter, may differ widely among these distinct populations.

This study is providing information about the geographic distribution of mercury, organic mercury, cadmium and selenium in livers and kidneys of eiders from different regions in the Canadian Arctic. The data compliment similar data collected in the early 1990s on levels of these contaminants in breast muscles (B. Braune, *pers. comm.*). It is also providing comparative information for two species of eiders harvested at the same locations and for three races (subpopulations) of common eiders. Finally, it is providing information about physiological condition and health status of these animals as they relate to contaminants exposure as a first step towards addressing the role of contaminants in population declines in these species.

Table 1. Mean concentrations and 95% confidence intervals (µg·g^{-1} dry wt.) of total and organic mercury and selenium in liver and cadmium in kidney of common and king eiders at three arctic locations. Total mercury, organic mercury and cadmium concentrations are geometric means and selenium concentrations are arithmetic means.

Location	Year	Species	Total Hg	Org. Hg	Se	Cd
Holman	1997	King eider (n=10)	1.67 1.39 - 2.00	—	37.4 28.5 – 46.2	111.7 76.6 – 162.9
		Common eider (n=10)	1.46 1.23 – 1.73	—	31.1 22.7 – 39.6	117.2 95.4 – 143.9
Belchers	1997	Common eider (n=10)	1.29 0.89 – 1.87	—	10.4 8.6 – 12.2	73.6 44.7 – 121.4
East Bay	1997	King eider (n=10)	2.65 2.07 – 3.41	2.27 0.95 – 5.41 n=7	20.2 14.9 – 25.4	161.9 139.0 – 188.6
	1997	Common eider (n=13)	1.63 1.32 – 2.00	1.20 n=2	20.6 16.3 – 24.9	68.1 57.7 – 80.4
	1998	Common eider (n=15)	3.74 3.20 – 4.38	1.51 0.78 – 2.92	18.5 13.6 – 23.3	162.6 139.6 – 189.5

ACTIVITIES IN 1998/99

Fifteen common eider females were collected during incubation at East Bay during July, 1998 (Figure 1). Livers and kidneys were preserved for trace element analysis. Blood samples were obtained for trace element analysis and assays of corticosterone and thyroid hormones. Morphological measurements of body size were made and the body mass, abdominal fat mass and the mass of various organs were recorded. Gastrointestinal tracts were preserved for counts of helminth parasites.

In the laboratory, corticosterone assays were completed for samples obtained in 1997 and 1998. Counts were completed for two groups of parasites for all samples collected in 1997. Body size/organ mass data were collated and preliminary analyses were done. Histological examination of prepared slides of liver and kidney, gonads and spleen tissue was done on 20 of 40 samples.

Currently, assays for thyroid hormones are being done as are counts of nematode and trematode parasites in 1997 samples and of all parasites in 1998 samples. Histological examination of prepared slides is continuing.

RESULTS

In 1997, 53 eider ducks were collected at three locations and in 1998, 15 female common eiders were collected at East Bay. Hepatic mercury concentrations ranged from < 1 to 6 µg·g^{-1} dry wt. and Se concentrations from 7 to 62 µg·g^{-1} dry wt. Renal cadmium concentrations ranged from 32 to 281 µg·g^{-1} dry wt. Geometric mean values and their 95% confidence intervals are shown in Table 1. Mean concentrations of trace elements in king eiders were approximately equal to or higher than those in common eiders during 1997. At East Bay, cadmium and mercury concentrations in common eiders increased from 1997 to 1998. In general, eiders from East Bay had higher concentrations of mercury and cadmium than their counterparts from the other sites while the opposite was true for selenium.

Principal components analyses of measurements of body size (Tables 2 and 3) were done for female king and common eider in 1997. All morphometric measurements loaded positively on the first principal component, which accounted for 37% and 62% of the total variance for king and common eiders respectively, indicating that the first principal component provided an indication of overall structural size. We expected that our measures of body mass, abdominal lipid stores and organ masses would be correlated with structural size; therefore, first

Table 2. Mean (95% confidence intervals) for body size measurements (mm) in king and common eiders at three arctic locations in 1997 and 1998. Bill depth is expressed as the geometric mean and 95% confidence interval. All other variables are expressed as arithmetic values and their 95% confidence intervals.

Study Area	Year	Species	Sex	Culmen length	Bill length	Tarsal length	Wing length	Keel length	Bill depth
Belchers	1997	Common	F	51.9	72.5	54.3	303	137	28.2
		eider	n=10	49.9-53.8	69.4-73.6	53.4-55.1	297-309	134-140	27.4-30.0
Holman	1997	King	F	33.4	58.0	48.8	274	109	16.0
		eider	n=10	32.4-34.5	57.1-58.8	47.6-50.0	269-279	107-111	15.6-16.3
		Common	F	48.1	68.7	54.8	306	121	21.6
		eider	n=10	46.0-50.2	66.4-71.0	53.7-55.8	299-313	118-124	20.9-22.4
East Bay	1997	King	F	34.0	56.5	46.8	281	107	17.7
		eider	n=6	32.1-36.0	55.1-58.0	46.0-47.7	274-288	100-114	16.3-19.3
			M	25.4	—	47.6	291	117	14.5
			n=4	20.4-30.7		44.8-50.8	274-308	109-125	13.0-16.2
		Common	F	47.7	63.1	47.8	283	110	22.7
		eider	n=13	46.2-49.2	61.8-64.3	46.2-49.4	277-288	108-112	22.1-23.2
	1998		F	47.3	63.4	50.6	281	112	22.4
			n=15	45.9-48.7	61.6-65.1	49.6-51.5	278-285	110-114	21.3-23.4

Table 3. Body morphometrics loadings on first principal component and % variance attributable to first principal component (PC1) for king and common eider females in 1997.

Variable	King Eider	Common Eider
Bill depth	0.40	0.38
Culmen length	0.56	0.38
Bill length	0.36	0.47
Tarsal length	0.21	0.37
Wing length	0.29	0.38
Keel length	0.52	0.47
% variance explained	37	62

principal component scores were included as covariates in all analyses of those variables. For common eider females, there were no significant differences among sites in body mass, breast muscle mass, spleen mass, abdominal fat mass, liver mass, kidney mass or heart mass after first accounting for the effect of the first principal component of body morphometric data ($p>0.05$, Table 4). However, king eider females at Holman differed significantly ($p<0.05$) from those at East Bay in abdominal fat mass, liver mass, kidney mass and heart mass.

Partial correlations between trace elements and body/organ mass variables are summarized in Table 5. For variables that did not differ significantly between sites, the correlation coefficient based on data from both East Bay and Holman is the most appropriate. For variables that did differ significantly between East Bay and Holman, correlation coefficients for each site are more appropriate. This preliminary analysis suggests that increasing cadmium concentrations in kidneys of king and common eiders are associated with declining spleen size (Table 5, Figure 2). However, in 1998, there were no significant correlations between body / organ mass and cadmium in nesting female common eiders at East Bay ($p>0.05$). Interestingly, selenium was positively related to body weight, abdominal fat mass, and kidney mass in these birds ($p<0.05$).

For common eiders, cestodes and acanthocephalan parasites differed significantly ($p \leq 0.05$) among sites while for king eiders, no such differences were found ($p>0.05$) (Table 6). Parasite counts were negatively correlated with mercury and cadmium concentrations in common eiders at the Belcher Islands (Table 7).

In 1997 and 1998, female common eiders at East Bay were blood sampled twice following capture: once soon after capture and again 10 minutes later. Corticosterone assays were done on these samples by radioimmunoassay and the difference in corticosterone measurements between the first and second sampling was recorded. This method was adapted from Gratto-Trevor *et al.* (1991) and is considered to be a

Table 4. Body mass, lipid stores and organ weights (g) in king and common eiders at three Arctic locations during 1997 and 1998. Liver, kidney and heart masses are geometric means and their 95% confidence intervals. Other variables are arithmetic means and 95% confidence intervals.

Study area	Year	Species	Sex	Body mass	Spleen mass	Breast muscle mass	Abdominal fat mass	Liver mass	Kidney mass	Heart mass
Belchers	1997	Common eider	F n=10	2125 1925-2325	—	211 190-233	—	—	—	—
Holman	1997	King eider	F n=10	1878 1789-1968	0.67 0.45-0.88	152 146-159	137 113-162	32.2 29.8-34.8	15.7 14.0-17.7	20.4 18.7-22.2
	eider	Common n=10	F 2374-2560	2487 0.70-1.29	0.99 202-220	211 72-138	105 54.5-76.2	64.5 23.4-28.7	25.9 23.2-31.4	27.0
East Bay	1997	King eider	F n=6	1833 1741-1925	0.43 0.23-0.63	154 141-167	71 54-89	49.1 41.9-57.6	17.7 16.7-18.8	17.0 15.3-18.8
			M n=4	1731 1544-1919	0.41 0.26-0.56	161 147-175	36 5-67	39.9 34.7-46.0	17.1 13.0-22.6	18.4 13.7-24.6
	1997	Common eider	F n=13	2073 1959-2186	0.70 0.46-0.93	169 163-175	75 56-94	63.5 57.8-69.8	22.3 20.8-23.9	22.2 21.2-23.2
	1998		F n=15	1283 1224-1341	0.59 0.46-0.72	134 126-142	12 7-16	24.9 22.7-27.4	10.8 9.9-11.7	13.5 12.2-15.0

Table 5. Pearson partial correlation coefficients between trace elements and body and organ mass variables after partialling out the first principal component measure of body size in king and common eider females at East Bay and Holman, 1997. * indicates $0.01 < (P > r) < 0.05$. ** indicates $(P > r) < 0.01$.

Study area	Species	Year	Variable	Trace Element		
				Hg (liver)	Se (liver)	Cd (kidney)
East Bay	Common eider	1997	Body mass	–0.11	0.19	0.70*
			Spleen mass	–0.21	–0.24	–0.34
			Abdominal fat mass	0.02	0.35	0.44
			Breast mass	0.11	–0.04	0.22
			Liver mass	0.44	–0.05	–0.23
			Kidney mass	0.38	–0.10	–0.36
			Heart mass	–0.36	0.22	0.41
	King eider		Body mass	0.25	0.16	–0.03
			Spleen mass	–0.44	0.87*	0.05
			Abdominal fat mass	–0.14	0.89*	0.01
			Breast mass	0.10	0.42	0.17
			Liver mass	0.30	–0.61	–0.45
			Kidney mass	–0.16	0.79	–0.14
			Heart mass	–0.14	0.64	0.06
Holman	Common eider		Body mass	0.36	0.68*	0.36
			Spleen mass	–0.88**	–0.30	–0.88**
			Abdominal fat mass	0.71*	0.46	0.50
			Breast mass	0.22	0.64	0.21
			Liver mass	–0.80*	–0.06	–0.54
			Kidney mass	–0.83**	0.02	–0.44
			Heart mass	–0.07	0.45	0.22
	King eider		Body mass	–0.17	–0.30	–0.11
			Spleen mass	–0.17	–0.19	–0.19
			Abdominal fat mass	–0.34	0.06	0.24
			Breast mass	–0.27	–0.33	–0.22
			Liver mass	–0.11	0.26	–0.21
			Kidney mass	–0.21	–0.05	–0.47
			Heart mass	–0.31	–0.24	–0.11
Both	Common eider		Body mass	–0.07	0.31	0.70**
			Spleen mass	–0.45*	–0.20	–0.46*
			Abdominal fat mass	0.26	0.32	0.52*
			Breast mass	–0.01	0.31	0.51*
			Liver mass	–0.06	–0.03	–0.23
			Kidney mass	–0.06	–0.03	–0.23
			Heart mass	–0.15	0.33	0.33
	King eider		Body mass	–0.20	0.21	0.12
			Spleen mass	–0.30	0.15	–0.49*
			Abdominal fat mass	–0.52*	0.65**	–0.07
			Breast mass	–0.11	–0.07	0.05
			Liver mass	0.41	–0.61*	0.16
			Kidney mass	0.22	–0.54*	–0.26
			Heart mass	–0.48	0.41	–0.18
East Bay	Common eider	1998	Body mass	–0.42	0.61*	0.16
			Spleen mass	0.42	0.36	–0.07
			Abdominal fat mass	–0.33	0.63*	0.004
			Breast mass	–0.18	0.49	0.06
			Liver mass	0.26	0.46	0.11
			Kidney mass	0.56*	0.60*	–0.30
			Heart mass	–0.11	0.48	0.22

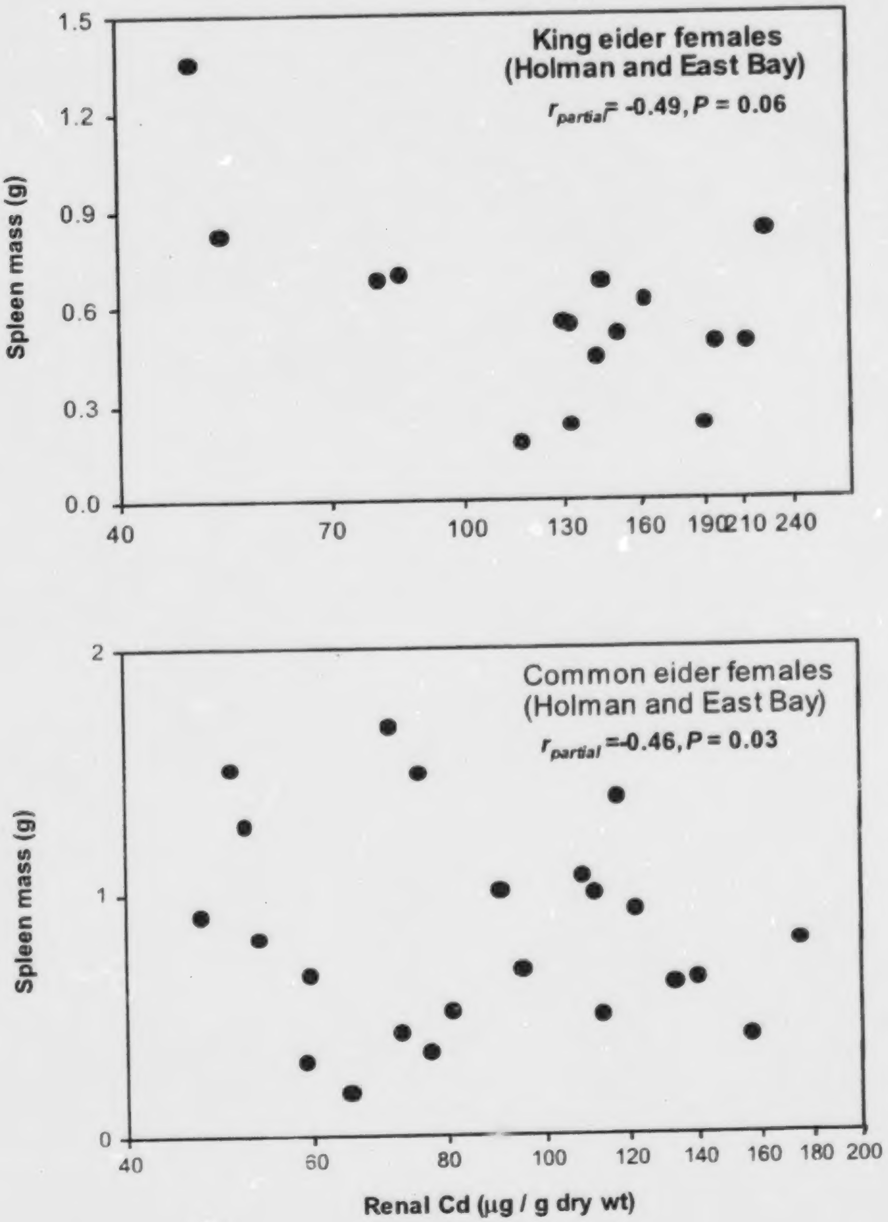

Figure 2. Relationship between renal cadmium and spleen mass in king and common eider females in 1997.

Table 6. Numbers of cestode and acanthocephalan worms in digestive tracts of king and common eiders at three arctic locations in 1997. Values are geometric means and their 95% confidence intervals.

Study area	Species	Sex (n)	Cestodes	Acanthocephala
Belchers	Common eider	F (n=10)	556 (42-7200)	16.3 (4.2-56.5)
Holman	King eider	F (n=10)	22 (3-130)	0.9 (0.2-2.3)
	Common eider	F (n=10)	62 (12-303)	0.4 (0-1.1)
East Bay	King eider	F (n=6)	11 (0-131)	0.1 (0-1.0)
		M (n=4)	4 (0-572)	0.2 (0-1.1)
	Common eider	F (n=13)	691 (319-1494)	18.6 (4.5-66.5)

Table 7. Pearson correlation coefficients between trace elements and cestode and acanthocephalan counts in the digestive tracts of king and common eider females at three arctic locations in 1997. * indicates $0.01 < (P > r) < 0.05$. ** indicates $(P > r) < 0.01$.

			Trace element		
Study area	Species	Parasite group	Hg (liver)	Se (liver)	Cd (kidney)
Belcher's	Common eider	Acanthocephala	–0.77**	0.11	–0.80**
		Cestoda	–0.84**	0.01	–0.67*
East Bay	Common eider	Acanthocephala	–0.04	–0.27	–0.02
		Cestoda	–0.01	0.05	–0.28
	King eider	Acanthocephala	0.42	–0.42	–0.62
		Cestoda	–0.063	0.15	0.62
Holman	Common eider	Acanthocephala	–0.04	0.1	0.28
		Cestoda	0.25	0.56	0.63*
	King eider	Acanthocephala	0.45	–0.26	–0.38
		Cestoda	0.20	–0.22	–0.04

'standardized' stress test for the purposes of this study. The difference in corticosterone measurement between the first and second blood sample was positively and significantly (p=0.02) correlated with renal cadmium concentration in 1998 (Figure 3) but not in 1997 (p=0.96).

Histological examination of selected tissues was performed as follows: tissues fixed in 10% neutral buffered formalin were embedded in paraffin and processed routinely for histology. Hemotoxylin and eosinstained 7-micrometer sections were examined using the light microscope. Liver and kidney have been examined from 20 birds and, when submitted, gonads and spleen were also examined. There was no evidence of renal tubular degeneration, hepatocellular degeneration or altered spermatogenesis. There was mild inflammation of portal triads in the liver and chronic ureturitis. The occasional Schistosome was present in the kidney. These lesions are interpreted as normal incidental lesions in a healthy bird.

DISCUSSION

Hepatic mercury concentrations reported in this study are similar to those reported in sea ducks from the west coast of Alaska (Henny *et al.* 1995) but were much lower than those in sea ducks from the California coast (Ohlendorf *et al.* 1986, Hoffman *et al.* 1998). Selenium concentrations in eiders in this study were slightly lower than those in sea ducks from Alaska and some areas of California (Henny *et al.* 1995, Hoffman *et al.* 1998) and markedly lower than those in spectacled eiders from St. Lawrence Island, Alaska recently reported by Trust et al. (1999), but were similar to those in sea ducks from San Francisco Bay (Ohlendorf *et al.* 1986). However, Cd concentrations were higher, especially in king eiders from East Bay. Cadmium concentrations reported in East Bay king eiders are among the highest reported in sea ducks from several locations (Frank 1986, Ohlendorf *et al.* 1986, Hontelez *et al.* 1992, Henny *et al.* 1995).

The correlation analyses reported above suggest a possible decline in spleen size and helminth parasite loads and an increase in stress response related to increasing cadmium level. However, these relationships must be regarded as speculative because the large number of statistical analyses reported here will increase the probability of finding a spurious significant result. Nevertheless, the corticosterone result is consistent with the increase in cortisol levels in fish following

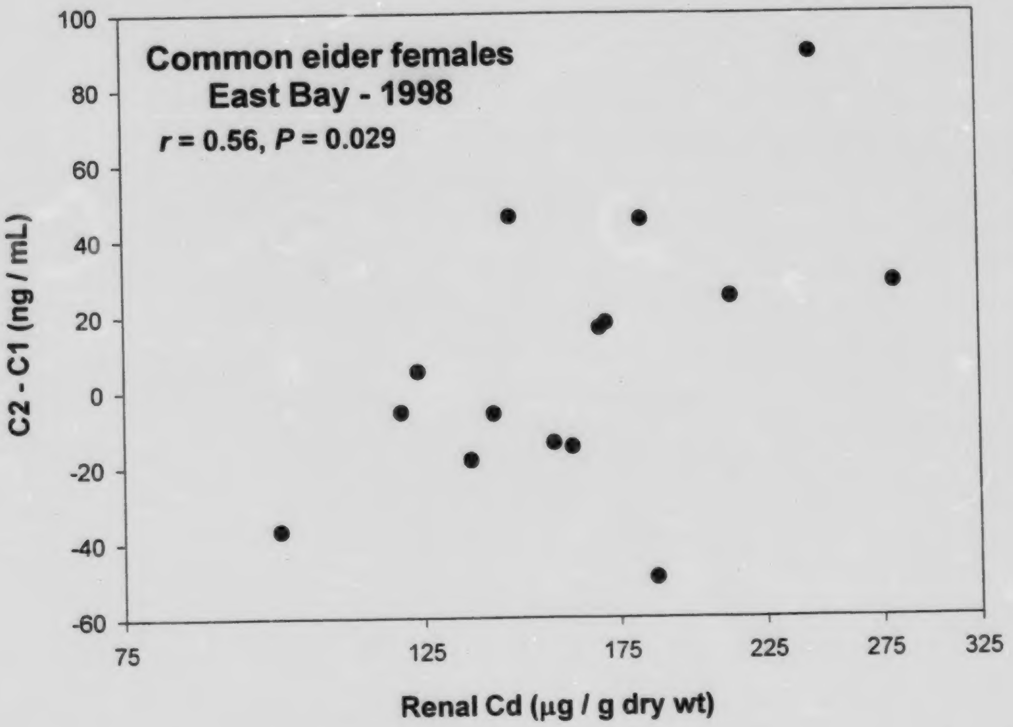

Figure 3. Correlation between renal cadmium and the difference between the second and first corticosterone samples taken at 10-minute intervals in common eider females trapped on nests at East Bay in 1998. C2 refers to the second blood sample for corticosterone and C1 to the first sample.

experimental exposure to cadmium reported by Ricard *et al.* (1998) and suggests that elevated cadmium concentrations may induce changes in endocrine status and stress response in common eiders. Furthermore, captive mallard ducks that were fed a restricted diet containing 50 µg $Cd \cdot g^{-1}$ food, exhibited higher plasma corticosterone levels than those on a similarly restricted diet containing low Cd levels (Di Giulio and Scanlon 1985). Interestingly, in 1998, when we found a significant correlation between cadmium and corticosterone, birds were sampled during incubation, a period when eiders normally do not eat, thus mimicking the food restriction in Di Giulio and Scanlon's (1985) study on captive mallards.

These results must be regarded as preliminary. During 1999, more appropriate multivariate analyses will be applied to this data to further examine relationships between these trace elements and body condition, parasite loads, and endocrine status of common eiders. The trace element data have been sent to Health Canada for evaluation for human consumption. The Northern Contaminants program will be notified of the results of their evaluation.

Expected Project Completion Date: The project should be completed by April, 2000.

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CONTAMINANTS IN COLONIAL WATERBIRDS FROM GREAT SLAVE LAKE

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Project Team: Keith A. Hobson, CWS, EC; Jacques Sirois, Department of Biology, University of Saskatchewan

OBJECTIVES

1. To document concentrations of chlorinated hydrocarbon contaminants, trace elements and polycyclic aromatic hydrocarbons in herring gulls and other colonial waterbird species from Great Slave Lake.
2. To examine spatial variation in contaminants in herring gull eggs at Great Slave Lake.
3. To examine seasonal variation in contaminants in adult herring gull livers at Great Slave Lake.
4. To determine whether contaminant levels in colonial waterbird species from Great Slave Lake are related to trophic levels as inferred from stable-nitrogen ($\delta^{15}N$) isotope analysis.

DESCRIPTION

Great Slave Lake is North America's fifth largest lake and drains a huge area of northwestern Canada, about 10% of Canada's land mass. It is also a source of Canada's largest river, the Mackenzie. The ongoing industrialization of parts of northwestern Canada has led to concerns about the ecological integrity of northern ecosystems including Great Slave Lake, particularly because many northerners depend to a large extent on locally available natural resources for their sustenance and as part of their cultural heritage (Muir *et al.* 1997). A particular concern is that contaminants transported through the Peace, Athabasca and Slave River systems could be deposited in the Slave River Delta on the southern shore of Great Slave Lake. There has also been speculation and some evidence that volatile organic contaminants and some trace elements have been increasing in concentration since the 1980s in northern latitudes, the result of a gradual movement of contaminants northward in air masses (Lockhart *et al.* 1995, Schindler *et al.* 1995) and that Great Slave Lake may be a 'sink' for such contaminants. Finally, domestic and industrial activities could affect contaminant levels in the northern arm of Great Slave Lake (Murdoch *et al.* 1988).

Colonial waterbirds comprise a group of species that are 'top-predators' in aquatic ecosystems in that they usually feed on small forage fish species as well as scavenge rough fish species that are captured in commercial fisheries but disposed of because of their non-commercial value. Thus, many colonial waterbirds may accumulate relatively high levels of contaminants that biomagnify through food chains (Government of Canada 1991). Contaminants are able to transfer from body burdens of laying females to eggs of these species. Eggs are also high in lipids, providing an excellent matrix for the deposition of lipophilic organic contaminants. Furthermore, colonial nesting habits and fidelity to nesting areas by colonial waterbirds provide a large and predictable source of eggs at a given site, making them easy to collect. These factors, coupled with the fact that the collection of eggs for contaminants biomonitoring is viewed as more ethical than the collection of adult animals, make colonial waterbirds effective and socially acceptable biomonitors of aquatic pollution. For such reasons, colonial waterbirds have been used as biomonitors in several studies of freshwater and marine ecosystem contamination (Fox and Weseloh 1987).

Great Slave Lake is an important breeding area for colonial waterbirds in northwestern Canada. Ten species (5 gulls, 4 terns and the parasitic jaeger) breed there. Over 6000 nests were located in comprehensive surveys during the late 1980s and early 1990s (Sirois *et al.* 1995).

A recent development in the field of contaminant modeling and analysis is the use of naturally occurring stable isotopes of nitrogen ($\delta^{15}N$) as a means of determining trophic level (reviewed by Kidd 1998). This technique is based on the fact that stable nitrogen isotope ratios in food webs show a stepwise increase with trophic level. Relative trophic position can thus be inferred from $\delta^{15}N$ values in consumers and their eggs (Jarmen *et al.* 1996). Stable nitrogen isotope data for all colonial waterbird species and for their supporting food chains indicate that contaminant biomagnification potential differs widely among bird species (Hobson *et al.* 1999) and that certain species should have higher levels of exposure to bioaccumulative contaminants, making them more sensitive indicators of contaminants exposure, all other factors being equal.

The objective of this study was to provide basic information about the distribution and bioaccumulation of contaminants in four species of colonial waterbirds from Great Slave Lake. In particular, we examined spatial and seasonal differences in contaminants in herring gulls (*Larus argentatus*) from Great Slave Lake and described the relationship between trophic position and contaminant levels for four species, including herring gulls, mew gulls (*L. canus*), caspian tern (*Sterna caspia*), and black tern (*Chlidonias niger*). Also, because of the presumed role of selenium in reducing mercury toxicity in birds (Scheuhammer 1987) coupled with the co-accumulation of these two elements in livers of birds reported by several investigators (*e.g.* Norheim 1987, Henny *et al.* 1991), sometimes at a molar ratio approaching 1:1 (Kim *et al.* 1996, Scheuhammer *et al.* 1998), we determined whether selenium and mercury were correlated in eggs of these species.

ACTIVITIES IN 1998/99

Samples were collected in 1995. During 1998, individual contaminant analyses were done on 19 herring gull eggs from four breeding colonies on Great Slave Lake: one in the North Arm on Yellowknife Bay, another in the East Arm on Francois Bay, a third on Egg Island near the outlet of the Slave River and a fourth on Brabant Island near the outlet of Great Slave Lake into the MacKenzie River (Figure 1). In addition, 10 livers from herring gulls sampled on the North Arm during May and August were analysed. Finally, three pooled eggs sampled from each of three other species – including black tern, caspian tern and mew gull – sampled in the North Arm were analysed for both contaminants and stable isotopes. Lipid-free yolk samples from eggs of these species and the herring gull were also analysed for $\delta^{15}N$.

RESULTS

There was no evidence of differences in chlorinated hydrocarbon concentrations in herring gull eggs among populations at four sampling sites (colonies) located in the East Arm (Francois Bay), Yellowknife Bay, the mouth of the Mackenzie River (Brabant Island), and the Slave River Delta area (Egg Island) (MANOVA: p=0.22; Table 1). Also, chlorinated hydrocarbon concentrations in liver did not differ between herring gull adults collected in early May and those collected in early August (MANOVA:

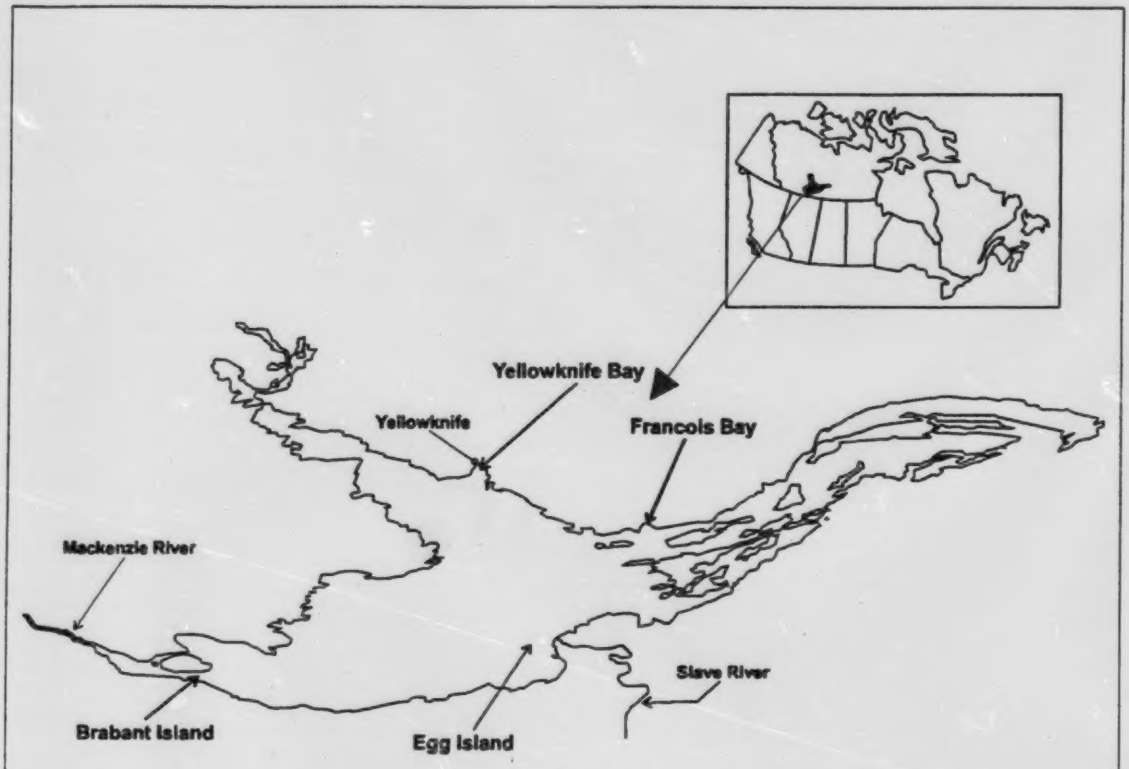

Figure 1. Map of Great Slave Lake showing sample collection locations.

Table 1. Mean concentrations and 95% confidence intervals (µg·g-1wet wt.) of chlorinated hydrocarbon contaminants in herring gull eggs from four sampling locations on Great Slave Lake, and factor scores from factor analysis.

Location	Σ DDTs	Σ Chlordanes	Σ PCBs	Factor1[a]
Brabant Island (n=4)	0.331 (0.181-0.605)	0.042 (0.025-0.070)	0.214 (0.097-0.471)	-0.507 (-2.342-1.328)
Francois Bay (n=5)	0.658 (0.224-1.933)	0.056 (0.029-0.106)	0.295 (0.145-0.598)	0.284 (-1.238-1.805)
Egg Island (n=5)	0.526 (0.340-0.813)	0.068 (0.047-0.098)	0.326 (0.268-0.397)	0.575 (0.132-1.018)
Yellowknife Bay (n=5)	0.352 (0.170-0.730)	0.027 (0.018-0.041)	0.043 (0.024-0.076)	-0.453 (-1.594-0.688)

[a] Values derived from individual sample scores from factor analysis of all organochlorine data. Factor 1 represented, most strongly, hexachlorobenzene, DDE, mirex, photo-mirex, oxychlordane, *cis*-nonachlor and several PCBs with ≥ four chlorine substitutions.

Table 2. Mean concentrations and 95% confidence intervals (µg·g^{-1}wet wt.) of chlorinated hydrocarbon contaminants in herring gull livers sampled prior to laying and after breeding.

Time Period	Σ DDTs	Σ Chlordanes	Σ PCBs	Factor1 [a]
May (n = 5)	0.601 (0.192-1.883)	0.029 (0.019-0.044)	0.269 (0.146-0.496)	0.108 (-1.126-1.342)
August (n = 5)	0.510 (0.322-0.807)	0.024 (0.010-0.057)	0.256 (0.157-0.416)	-0.108 (-1.487-1.271)

[a] See comment in Table 1.

Table 3. Mean concentrations and 95% confidence intervals (µg·g^{-1}wet wt.) of PAH concentrations in herring gull livers sampled prior to laying and after breeding.

Time Period	Acenaphthylene	Naphthalene	Total PAHs
May (n = 5)	0.003 (0.002-0.006)[a]	0.011 (0.005-0.024)	0.014 (0.007-0.029)
August (n = 5)	ND-0.002[b]	0.016 (0.009-0.030)	0.017 (0.010-0.031)

[a] n = 4

[b] Range of values. Below detection limit (0.001 µg·g^{-1} wet wt.) in 2 of 5 samples.

Table 4. Mean concentrations and 95% confidence intervals (µg·g^{-1}dry wt.) of selenium and mercury in herring gull eggs from four sampling locations on Great Slave Lake.

Location	Selenium	Total Mercury
Brabant Island (4)	3.918 (3.459-4.437)	0.780 (0.540-1.125)
Francois Bay (5)	2.524 (2.131-2.990)	1.100 (0.656-1.842)
Egg Island (5)	2.411 (2.165-2.686)	0.464 (0.363-0.593)
Yellowknife Bay (5)	1.790 (1.356-2.363)	0.302 (0.222-0.412)

Table 5. Mean concentrations and 95% confidence intervals (µg·g^{-1}dry wt.) of selenium and mercury in adult herring gull livers sampled prior to laying and after breeding.

Time Period	Selenium	Total Mercury
May (n = 5)	9.048 (5.660-14.464)	3.521 (1.698-7.301)
August (n = 5)	3.295 (2.200-4.934)	1.396 (0.923-2.111)

Table 6. Chlorinated hydrocarbon contaminants (µg·g^{-1}, wet wt.) and mercury (µg·g^{-1}dry wt.) in other species of Great Slave Lake and in herring gulls at other locations.

Lake/Province	Site	Species	Tissue	N	Year	Hg[b]	ΣDDT	DDE	ΣPCB	Aroclor 1260	Aroclor 1254:1260	oxy-Chlordane	ΣChlordane	Reference[d]
Great Slave Lake	North Arm	Black tern	Egg	3	1995	0.42	0.11	0.11	0.07	0.08	0.15	0.002	0.01	1
	North Arm	Caspian tern	Egg	3	1995	1.15	1.77	1.74	0.71	0.64	1.44	0.005	0.03	1
	—	Herring gull	Egg	19	1995	0.66	0.47	0.45	0.27	0.22	0.57	0.02	0.048	1
	North Arm		Liver	10	1995	2.46	0.56	0.69	0.26	0.20	0.58	0.02	0.03	"
Great Slave Lake	North Arm		Egg	10	1992	0.64	0.61	0.61	0.39	0.42	0.88	0.02	—	2
	Lutsel K'e	Lake Trout[a]	Muscle	N/A	1993	—	0.0095	—	0.0268	—	—	—	0.0174	3
		Burbot[a]	Liver	N/A	1993	—	0.0401	—	0.116	—	—	—	0.0787	"
	Hay River	Lake Trout[a]	Muscle	N/A	1994	—	0.0061	—	0.0143	—	—	—	0.0107	"
Lake Ontario	Snake Island	Herring gull	Egg	10	1996	—	—	2.62	14.00	—	—	—	—	4
				10	1988	—	5.20	5.15	—	11.18	26.67	0.16	—	5
				13	1992	0.913[c]	—	—	—	—	—	—	—	6
	Niagara River		Egg	10	1996	—	—	1.51	11.28	—	—	—	—	4
				10	1988	—	1.73	1.69	—	5.54	12.45	0.001	—	5
				13	1992	0.696[c]	—	—	—	—	—	—	—	6
Lake Erie	Port Colborne L.		Egg	10	1996	—	—	1.15	10.02	—	—	—	—	4
				10	1988	—	1.96	1.93	—	8.05	17.59	0.11	—	5
				13	1992	0.609[c]	—	—	—	—	—	—	—	6
	Middle Island		Egg	10	1996	—	—	1.35	21.00	—	—	—	—	4
				10	1988	—	2.24	2.21	—	17.20	37.40	0.13	—	5
				13	1992	0.652[c]	—	—	—	—	—	—	—	6
Quebec	George River		Egg	5	1991	—	—	—	2.66	—	6.27	—	—	2
Yukon	Whitehorse		Egg	5	1994	—	—	—	0.33	0.29	0.81	—	—	"
Quebec/Ontario	L. Ontario / St. Lawrence R.	Black tern	Egg	13	1989–1996	0.34	—	0.37	1.46	—	2.29	—	0.05	7
Manitoba	—		Egg	21	1986	—	—	0.19	—	—	<0.8	—	—	8
Lake Michigan	—	Caspian tern tern	Egg	—	1991	—		2.91	6.79	—	12.49	—	0.24	9
Lake Huron	—			—				2.55	6.28	—	11.47	—	0.22	"
Lake Ontario	—			—				3.58	8.76	—	16.90	—	0.22	"
Texas	Laguna Madre			10	1993–1994	0.61	—	0.11	—	0.56[e]	—	—	—	10

[a] fish from Great Slave Lake were females.

[b] µg·g-1 dry wt.

[c] converted from wet wt. values (used 77% as moisture content which was obtained by averaging herring gull egg moisture contents from Great Slave Lake).

[d] 1 = this study; 2 = Braune, CWS, Ottawa, *unpubl.*; 3 = Evans 1994; 4 = Hughes *et al.* 1998. 5 = Bishop *et al.* 1992; 6 = Kosher *et al.* 1996; 7 = Weseloh *et al.* 1997; 8 = DeSmet and Shoesemith 1988; 9 = Ewins *et al.* 1994; 10 = Mora 1996.

[e] Not stated whether PCBs expressed as Aroclor 1254 or 1260.

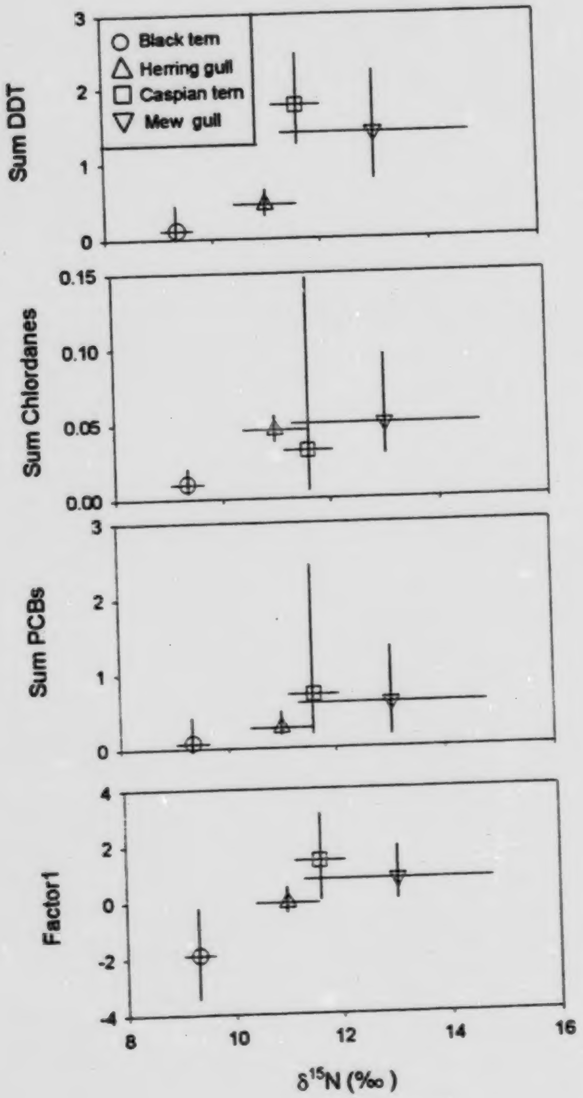

Figure 2. Relationship between stable-nitrogen isotopes in lipid-free egg yolk of four waterbird species and their corresponding contaminant concentrations in whole eggs (wet wt, µg·g-1). Values are means (± 95% confidence interval). Factor 1 scores are from a factor analysis of all the data on organochlorines in eggs.

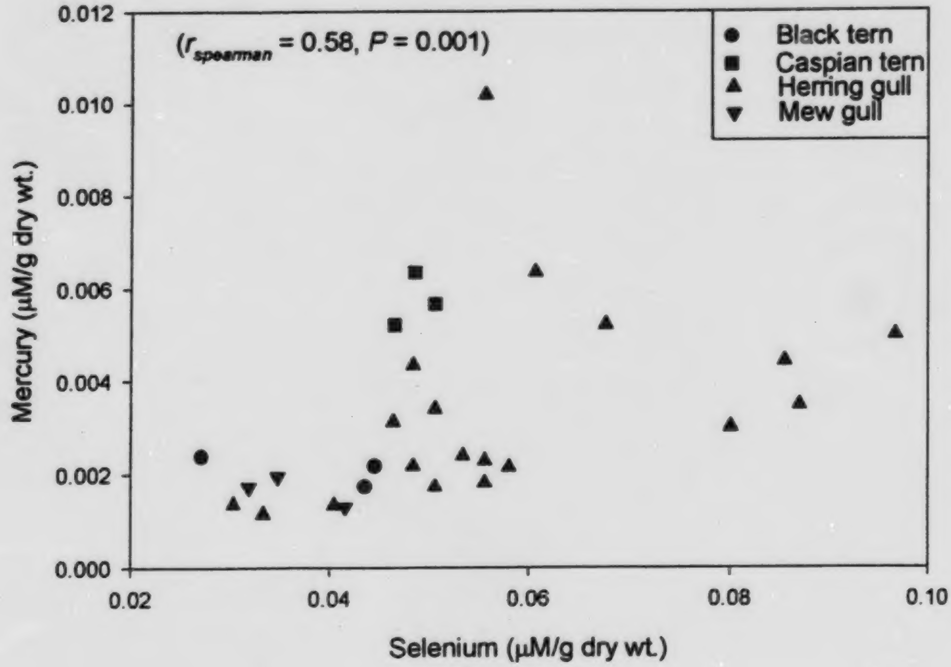

Figure 3. Relationship between concentrations (µ·g^{-1}dry wt.) of selenium and mercury in eggs of four waterbird species.

p=0.98; Table 2). Polycyclic aromatic hydrocarbons in herring gull livers were low and also did not differ between May and August samples (Table 3). Selenium and mercury concentrations in eggs differed significantly among the four breeding colonies (ANOVA: p <0.001), possibly due to among-site differences in food web structure or in actual concentrations of selenium and mercury in local food webs (Table 4). Selenium and mercury concentrations in adult herring gull livers declined between May and August (ANOVA: p = 0.002, p = 0.02; Table 5). There was evidence that chlorinated hydrocarbon concentrations in eggs of herring gulls, mew gulls, caspian terns and black terns were related to their trophic positions as inferred from δ^{15}N values in lipid-free egg yolks (Figure 2). Chlorinated hydrocarbon contaminants differed among the four species (MANOVA: p<0.0001). In general, concentrations of contaminants in caspian tern and mew gull eggs were significantly higher than in herring gull eggs (p< 0.05), which, in turn were significantly higher than those in black tern eggs (Figure 2). There was a close correspondence between contaminant concentrations in eggs and δ^{15}N values, suggesting a relationship between contaminant concentrations and trophic level of laying females. Selenium and mercury were positively correlated in eggs of these species (r=0.58, p<0.001; Figure 3). Chlorinated hydrocarbon contaminants in these colonial waterbirds were much higher than in fish from Great Slave Lake but were lower than in their conspecifics from the Great Lakes (Table 6). It is probable that a relatively large proportion of the chlorinated hydrocarbon contaminant load in colonial waterbird eggs on Great Slave Lake results from exposure to and storage of such contaminants at more heavily contaminated wintering and staging areas.

DISCUSSION

We found no evidence of spatial variability in chlorinated hydrocarbon contaminant levels in herring gull eggs from Great Slave Lake. This finding contrasts with that of Evans (1995, 1997), who reported spatial variability in organochlorine contaminants in fish, invertebrate and sediment samples from Great Slave Lake. This may be the result of: (1) small sample sizes resulting in low statistical power; (2) broad feeding ranges of gulls on Great Slave Lake such that their nesting location did not reflect their feeding location; or (3) contaminants in their eggs originating from endogenous sources in laying females from wintering areas away from Great Slave Lake.

There was evidence of spatial variability in selenium and mercury in herring gull eggs on Great Slave Lake. Possible explanations are: (1) within-lake differences in mercury and selenium at the base of food chains; and (2) differences in food chain structure at various locations of Great Slave Lake, resulting in differences in bioaccumulation potential (Atwell *et al.* 1998).

There was no evidence of a decline in chlorinated hydrocarbon contaminant concentrations in adult herring gulls from Great Slave Lake between the pre-laying (mid-May) and post-breeding periods (early August). Small sample sizes coupled with high variability in contaminant levels may have contributed to this result. Alternatively, slow clearance rates for many chlorinated hydrocarbon contaminants (Norstrom *et al.* 1986, Clark *et al.* 1987) may result in relatively stable tissue concentrations even in females which transfer a portion of their contaminant burdens to eggs each spring (Norstrom *et al.* 1986). In contrast to the chlorinated hydrocarbons, significant decreases were observed in selenium and mercury in birds over the breeding season. The decrease in selenium is consistent with movement from a marine to a freshwater environment by these birds during the summer, coupled with its rapid depuration from tissues (Heinz *et al.* 1990). Such an effect was noted using stable carbon and nitrogen isotopic data from colonial waterbirds on Great Slave Lake by Hobson *et al.* (1999). Selenium tends to be elevated in marine biota compared to freshwater biota from non-polluted areas (Eisler 1985).

Mercury in tissues of birds also decreased significantly from May to August, perhaps signifying that herring gulls 'cleanse' themselves of mercury during their summer residency on Great Slave Lake. For females, a small portion of the mercury was probably excreted in eggs (Heinz 1979). The process of feather molt is associated with a major redistribution of mercury from soft tissues to feathers in birds (Braune and Gaskin 1987) and may have accounted for much of the reduction in mercury (and perhaps selenium as well) in livers of herring gulls between spring and mid-summer.

Several previous studies have demonstrated a relationship between trophic structure, as measured using $\delta^{15}N$ analyses, and persistent chlorinated hydrocarbon and mercury concentrations in food webs (Broman *et al.* 1992, Jarmen *et al.* 1996, Atwell *et al.* 1998). In this study, trophic level and contaminants concentrations were lowest in black terns, followed by herring gulls. Mew gulls and caspian terns with higher $\delta^{15}N$ values of their eggs also contained contaminant concentrations that were higher than those in herring gull and black tern eggs. Our data suggest a possible link between diet and chlorinated hydrocarbon contaminant concentrations in eggs of these species. However, we recognize that the relationship between trophic position as inferred from stable isotope analysis, and tissue contaminant concentrations may be obscured by differences in turnover rates of lipophilic contaminants and protein and its associated elemental carbon and nitrogen. While $\delta^{15}N$ values in soft tissues of animals may reflect more recent diet because of a relatively faster turnover rate of protein (Hobson and Clark 1992), lipophilic chlorinated hydrocarbon contaminants turnover much more slowly (Norstrom *et al.* 1986, Clark *et al.* 1987). For migratory species which may accumulate contaminants and nutrients at different locations and during different times of the year, it may be difficult to establish a relationship between contaminant concentrations in eggs and trophic level as inferred from stable isotope ratios in eggs.

In this study, selenium and mercury were correlated in the eggs of the four species, suggesting that these two elements co-accumulate in birds' eggs. Sell (1977) noted that when selenium and mercury were simultaneously administered to chickens and quail, a higher proportion of the total mercury dose was deposited in eggs than when mercury was administered alone. While there are many examples of selenium and mercury co-accumulation in livers of wild birds (Norheim 1987, Henny *et al.* 1991), few such examples exist for eggs. Selenium and mercury were not correlated in eggs of Franklin's gulls, black-crowned night herons and double-crested cormorants (Burger and Gochfeld 1996) or in the eggs of herring gulls (Burger and Gochfeld 1995). In fact, this may be the first study wherein a positive correlation between these two elements in eggs has been reported.

Expected Project Completion Date: This project was completed March 31, 1999.

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Human Health

ADVERSE DEVELOPMENTAL EFFECTS IN PIGS FOLLOWING *IN UTERO* AND LACTATIONAL EXPOSURE TO ORGANOCHLORINES: EFFECTS ON MALE REPRODUCTIVE FUNCTION

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Project Team: Janice L. Bailey, Bruno Bérubé, Jean-Paul Laforest, Marc-André Sirard, and Robert Sullivan, Centre of Research in Biology of Reproduction (CRBR), Laval University; Éric Dewailly, Québec Public Health Centre

OBJECTIVES

1. To assess the impact of pre- and postnatal exposure to organochlorine (OC) mixtures found in the Arctic on the development and function of the male reproductive system, using the pig as the animal model.

DESCRIPTION

The development and maintenance of reproductive tissues is to a large extent controlled by steroid hormones. Some environmental chemicals mimic, while others antagonise natural hormone activity when tested with *in vitro* assays or in whole animal models. Studies dating back to the late 1960s identified 1-[2-chlorophenyl]-1-[4-chlorophenyl]-2,2,2-trichloroethane (*o,p'*-DDT), a minor constituent of technical DDT, as a weak estrogenic compound capable of causing an augmentation of rat uterine weight in the classic immature female rat model (Bitman *et al.* 1969). This compound and a few others sharing estrogenic properties have been implicated in abnormal sexual development in reptiles (Guillette *et al.* 1994, 1995) and birds (Fry and Toone 1981) as well as feminised responses in male fish (Jobling *et al.* 1995).

Certain male reproductive tract disorders (cryptorchidism, hypospadias, testicular cancer) have been reported to be increasing in parallel with the introduction of xenoestrogens such as DDT into the environment. Furthermore, a decrease of semen quality was also reported in certain regions of the world during the last half of the century (Carlsen *et al.* 1992, Auger *et al.* 1995). Although these alterations are thought to be mediated by the estrogen receptor, they are also consistent with inhibition of androgen receptor-mediated events. Kelce *et al.* (1995) identified the major and persistent DDT metabolite, 1,1-*bis*[4-chlorophenyl]-2,2-dichloroethylene (*p,p'*-DDE), as a potent anti-androgenic agent in male rats. In addition to inhibiting androgen binding to the androgen receptor, this compound when administered to pregnant dams also induced characteristic anti-androgenic effects in male pups (reduced anogenital distance; presence of thoracic nipples). Treatment with *p,p'*-DDE at weaning delayed the onset of puberty, while treatment of adult rats resulted in reduced seminal vesicle and ventral prostate weights. 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is yet another organochlorine which has been shown to alter sexual development in male rats (Mably *et al.* 1992). Decreases in epididymis and cauda epididymis weights, daily sperm production and cauda epididymal sperm number were observed at day 120 and at most earlier times, when a dose as little as 64 ng·kg^{-1} was administered to dams on day 15 of gestation. A number of compounds structurally related to TCDD, including other 2,3,7,8-chloro-substituted dibenzo-*p*-dioxins, dibenzofurans, as well as non *ortho*- and mono *ortho*-substituted polychlorinated biphenyl (PCB) congeners, bind to the Ah receptor and display similar toxicological properties, albeit with varying potency (Safe 1990). Results of the cancer bioassay conducted by Kociba *et al.* (1978) showed that TCDD possesses anti-estrogenic properties, as revealed by the striking decrease in the incidence of mammary tumours observed in females rats treated over two years with daily doses of 10 ng·kg^{-1} body weight. Moore *et al.* (1997) recently produced data suggesting that hydroxy metabolites of several PCB congeners also possess anti-estrogenic properties, using two estrogen responsive *in vitro* bioassays.

Typical organochlorine mixtures found in highly exposed human populations contain a large variety of organochlorine compounds, including substances with estrogenic, anti-estrogenic or anti-androgenic capacities. One may therefore anticipate that complex real life mixtures, composed of numerous compounds which can interact with different receptors involved in cell differentiation and growth, could also generate disproportionate biological stimuli. This, in turn, may interfere with the normal development of the male reproductive system and result in impaired male fertility in adulthood. The proposed study aims to investigate the effect of a complex organochlorine mixture similar to that found in highly exposed human populations on the development of the male reproductive system, using the pig as the experimental model.

The pig has been selected as the experimental model in the proposed study for numerous reasons. The team members have considerable experience with this species and are experts in porcine physiology. Moreover, there are many advantages of a porcine model: pigs reach puberty early (6 months), have a short gestation period (~ 15 weeks) and are litter-bearing animals (~10 piglets). The Animal Science Department at Laval University will provide the infrastructure necessary to house the animals and perform the experiments. With respect to the digestive, reproductive, endocrine and other systems, porcine physiology is very similar to human physiology (Newman 1996). Furthermore, all tests commonly used to evaluate male fertility can be easily performed on boar, which is not the case for usual laboratory species. For example, it is essentially impossible to obtain ejaculated semen from rodents, hence many parameters cannot be assessed (e.g. semen volume, seminal plasma characteristics). Furthermore, rodents are sacrificed in order to collect epididymal sperm, so multiple analyses on the same individual would be impossible. In fact, certain tests can be more easily performed in pigs than in humans (e.g. the zona pellucida-induced acrosome reaction and *in vitro* fertilization).

ACTIVITIES IN 1998/1999

Early in 1998, final adjustments to the protocol were made, mainly with regard to the dosing regimen and the exact composition of the organochlorine mixture. Following negotiations with Laval University and the Québec Ministry of the Environment, arrangements were made for the disposal of contaminated carcasses and feces. Additional protocols were elaborated to study the impact of the *in utero* and lactational exposure to OCs on the immune system function and the neuro-development in the F1 generation. Animals have been purchased, acclimated to their quarters and dosing began during the first week of June 1998. Insemination of the first females using the semen from an untreated boar (Duroc) was performed after 20 weeks of treatment with the OC mixture. Three series of insemination took place between October 1998 and March 2000. The birth of the first litter occurred in mid-February while the last litter was born in mid-June 1999. In all, 11 out of 15 sows became pregnant, delivered and nursed their piglets for three weeks. Ten male piglets from 2 to 3 sows per dosing group will be tested for reproductive function.

OVERVIEW OF THE RESEARCH PROTOCOL AND LABORATORY METHODS

Animal Treatment

Sixteen Landrace-Yorkshire-Duroc sows were randomly allocated to four treatment groups. Animals in each group received orally different doses of an organochlorine mixture from four months of age until the weaning of their first litter. The composition of the OC mixture is described in Table 1 and was designed to approximate that found in the blubber of ringed seal from Inukjuak (D. Muir, *pers. comm.*). Organochlorines were dissolved in corn oil to reach the appropriate concentration and the resulting solution was placed in 2-mL gelatin capsules. Animals were treated on Mondays, Wednesdays and Fridays. The first group received 1 µg PCB/kg body weight/day, the second group 10 µg PCB/kg/day and the third group 100 µg PCB/kg body weight/day. Animals in the fourth group (control group) were administered corn oil only. Animals were weighed each

Table 1. Composition of the organochlorine mixture.

Compound	CAS number	% weight
PCB mixture[a]		32.59
technical chlordane	57-74-9	21.3
p,p'-DDE	72-55-9	19.24
p,p'-DDT	50-29-3	6,79
technical toxaphene	8001-35-2	6.54
α–HCH	319-84-6	6.17
aldrin	309-00-2	2.52
dieldrin	60-57-1	2.09
1,2,4,5-tetrachlorobenzene	95-94-3	0.86
p,p'-DDD	72-54-8	0.49
β–HCH	319-85-7	0.46
hexachlorobenzene	118-74-1	0.35
mirex	2385-85-5	0.23
γ–HCH	58-89-9	0.20
pentachlorobenzene	608-93-5	0.18

[a] a mixture containing 2,4,4'-trichlorobiphenyl (320 mg), 2,2',4,4'-tetrachlorobiphenyl (256 mg), 3,3',4,4'-tetrachlorobiphenyl (1.4 mg), 3,3',4,4', 5-pentachlorobiphenyl (6.7 mg), Aroclor 1254 (12.8 g) and Aroclor 1260 (19.2 g).

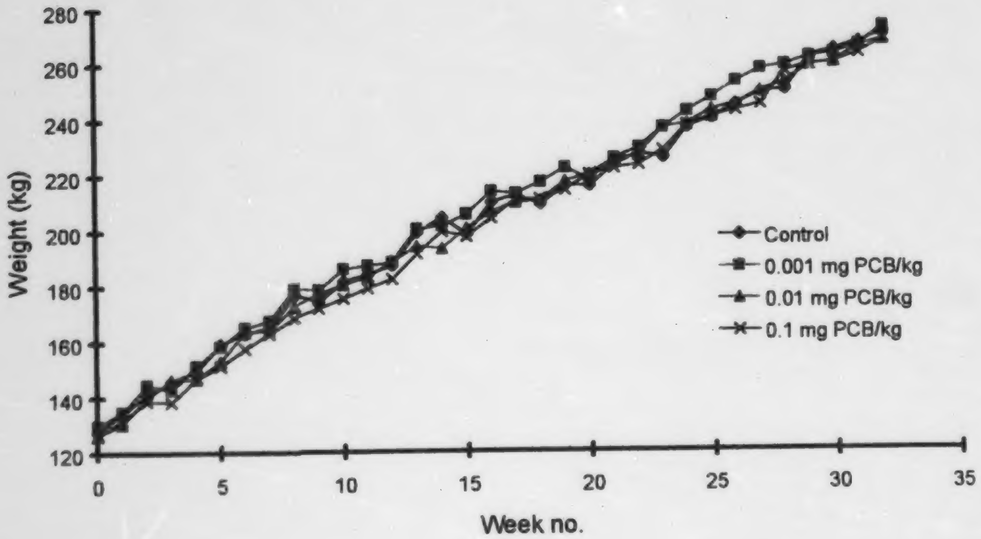

Figure 1. Body weight gain during the first 34 weeks of dosing with the organochlorine mixture. Each point represents the mean of four animals, except for the group receiving the 0.01 mg·kg^{-1} dose for which N = 3 starting on the 8th week.

week and the plasma concentrations of the various OCs was monitored by monthly blood sampling performed throughout the study.

At puberty, females were inseminated with semen from an untreated boar (Duroc). Ten male piglets from each of the four treatment groups were nursed by their sow, such that the offspring will also be exposed to organochlorines present in maternal milk. At weaning, the juvenile male pigs are receiving the standard diet and will not be treated with OCs. Again, blood samples will be collected monthly for organochlorine determination. At puberty, the semen parameters of the young boars from each treatment group will be evaluated to assess the status of their reproductive systems. Parameters of male reproductive function to be assessed include: sperm concentration and total sperm number/ejaculate; sperm morphology (Mortimer 1985); motility, and viability (deLamirande and Gagnon 1991); sophisticated computer assessments of sperm motion (Bailey *et al.* 1994, Lapointe *et al.* 1995); nuclear integrity and chromatin structure (Evenson 1991); functional assays of capacitation and the acrosome reaction (Tardif *et al.* 1996); the hypo-osmotic test (Jeyendran *et al.* 1984); quantification of a known fertility protein of epididymal origin (Boué and Sullivan 1996). Details on these tests and the analytical procedure for OC analysis were provided in Ayotte *et al.* (1999). Results obtained from the treated boars will be compared to controls using analyses of variance. In addition, tissue samples will be collected at slaughter to investigate the histology of the reproductive system. A tissue banking system will be established in order to allow for future analyses on tissue/organ samples.

RESULTS

Figure 1 shows the mean weight gain of animals belonging to the four groups during the first 34 weeks of dosing. Weight gain was similar in all groups. During the seventh week, one sow from the mid-dose group (10 µg·kg^{-1}) died of hemorrhagic enteritis, likely of allergic origin. All other animals were examined by a veterinarian who has a long experience with this animal species and they were all found to be in good health.

Organochlorines were determined in plasma samples at 4, 14, 20 and 30 weeks. Tables 2 and 3 present mean concentrations of organochlorines in plasma samples collected after 30 weeks of treatment. Between-animal variability is small, with coefficient of variation (CV) generally below 10%. Organochlorine compounds were not found in plasma samples from animals belonging to the control group. Concentrations of the main OCs in samples from sows in the 100 μg·kg^{-1} dose group are 7-10 fold greater than those measured in samples from animals in the 10 μg·kg^{-1} group. Only the most abundant and persistent compounds were detected in plasma samples from the low dose (1 μg·kg^{-1}) group.

Figure 2 shows the rise in plasma concentrations of three PCB congeners in animals from the high dose group. These results show that steady state was reached for the least persistent congeners PCB-52 and PCB 118, while the concentrations of the long-lived congener PCB-153 were still increasing. On a lipid basis, total PCB concentrations of 0.2, 2 and 20 mg·kg^{-1} are expected during pregnancy for the 1, 10 and 10 μg·kg^{-1} dose groups, respectively.

Finally, characteristics of the male piglets at birth are presented in Table 4. There was no statistically significant difference between groups with regard to either birth weight, length or ano-genital distance. Analysis of OCs in plasma samples collected from male piglets are underway.

DISCUSSION/CONCLUSIONS

This male reproductive study is progressing well and results from OC determination in plasma samples collected after 30 weeks of dosing indicate that steady state is approached for most OCs, except the most persistent compounds. During the treatment period, sows gained weight normally and there were no signs of overt toxicity. No difference in physical characteristics of the piglets at birth was noted between groups. Evaluation of the male reproductive function will be conducted in 7-month old boars starting in September 1999.

Expected project completion date: March 31, 2000

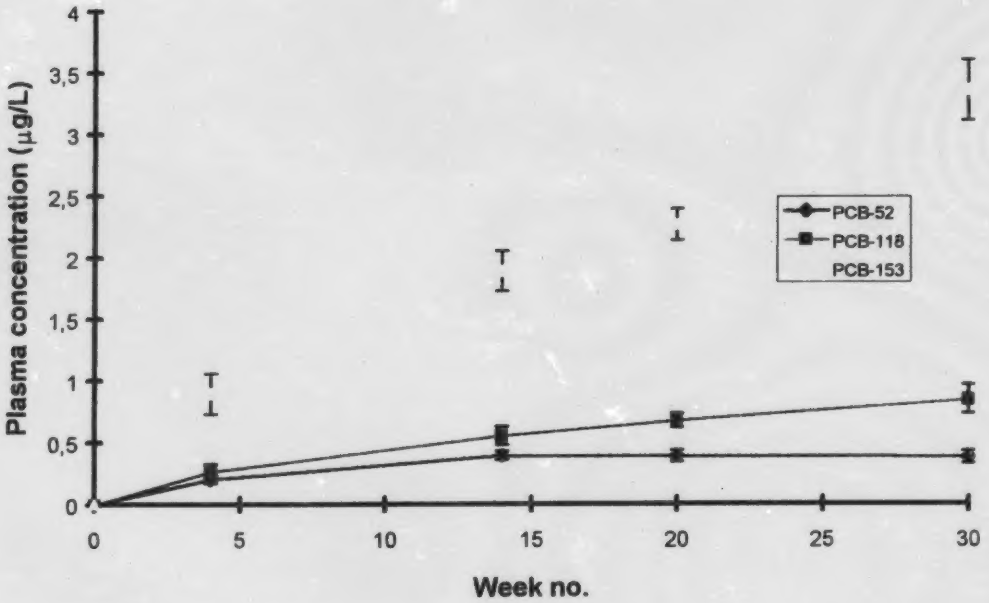

Figure 2. Temporal trend of PCB congener concentrations in plasma of sows during treatment with the organochlorine mixture 100 μg·kg^{-1}.

Table 2. Concentration ($\mu g \cdot L^{-1}$) of various PCB congeners in plasma samples collected from sows treated during 30 weeks with the organochlorine mixture and from control animals.

	Controls	1 µg·kg⁻¹	10 µg·kg⁻¹	100 µg·kg⁻¹
PCB congener				
28	ND[a]	ND	ND	0.03 ± 0.01[b]
52	ND	ND	0.07 ± 0.01	0.38 ± 0.05
99	ND	ND	0.07 ± 0.01	0.49 ± 0.02
101	ND	ND	0.13 ± 0.02	0.42 ± 0.17
105	ND	ND	0.03 ± 0.01	0.18 ± 0.03
118	ND	ND	0.13 ± 0.01	0.85 ± 0.12
128	ND	ND	0.05 ± 0.01	0.30 ± 0.02
138	ND	0.03 ± 0.01	0.38 ± 0.04	2.82 ± 0.09
153	ND	0.03 ± 0.01	0.42 ± 0.06	3.36 ± 0.25
156	ND	ND	0.06 ± 0.01	0.43 ± 0.01
170	ND	0.02 ± 0.01	0.16 ± 0.02	1.16 ± 0.03
180	ND	0.03 ± 0.01	0.31 ± 0.05	2.41 ± 0.19
183	ND	ND	0.08 ± 0.01	0.49 ± 0.03
187	ND	0.02 ± 0.01	0.15 ± 0.02	1.07 ± 0.04
ΣPCBs[c]	ND	0.12 ± 0.03	2.03 ± 0.26	14.4 ± 0.6

[a] ND = not detected

[b] arithmetic mean ± standard deviation

[c] total concentration of all PCB congeners

Table 3. Concentration ($\mu g \cdot L^{-1}$) of various chlorinated pesticides and metabolites in plasma samples collected from sows treated during 30 weeks with the organochlorine mixture and from control animals.

	Controls	1 µg·kg⁻¹	10 µg·kg⁻¹	100 µg·kg⁻¹
Aldrin	ND[a]	ND	ND	ND
ß-HCH	ND	ND	0.05 ± 0.01[b]	0.30 ± 0.02
cis-chlordane	ND	ND	ND	ND
trans-chlordane	ND	ND	ND	ND
cis-nonachlor	ND	ND	0.02 ± 0.01	0.04 ± 0.04
p,p'-DDE	0.07 ±0.06	0.21 ± 0.03	2.40 ± 0.31	19.0 ± 2.2
p,p'-DDT	ND	0.07 ± 0.01	0.68 ± 0.07	4.3 ± 0.2
hexachlorobenzene	ND	ND	0.07 ± 0.02	0.58 ± 0.10
mirex	ND	ND	0.06 ± 0.01	0.43 ± 0.04
oxychlordane	ND	ND	0.07 ± 0.01	0.62 ± 0.02
trans-nonachlor	ND	ND	0.11 ± 0.04	0.55 ± 0.10
α-HCH	ND	0.03 ± 0.01	0.27 ± 0.09	1.80 ± 0.20
p,p'-DDD	ND	ND	0.03 ± 0.01	0.11 ± 0.02
dieldrin	ND	ND	0.22 ± 0.09	1.20 ± 0.12
heptachlor	ND	ND	ND	ND
heptachlor epoxide	ND	ND	ND	0.14 ± 0.03
lindane	ND	ND	ND	ND
pentachlorobenzene	ND	ND	ND	0.04 ± 0.01
toxaphene congeners				
Parlar no. 26 (T2)	ND	ND	ND	ND
Parlar no. 32	ND	ND	ND	ND
Parlar no. 50 (T12)	ND	ND	ND	ND
Parlar no. 62 (T20)	ND	ND	ND	ND
Parlar no. 69	ND	ND	ND	ND

[a] ND = not detected

[b] arithmetic mean ± standard deviation

Table 4. Physical characteristics of piglets at birth

Treatment[a]	Body weight (kg)	Length (cm)	Ano-genital distance (cm)
Control	1.72 ± 0.17[b]	37.6 ± 1.4	13.2 ± 1.0
1 μg PCBs/kg	1.43 ± 0.21	36.3 ± 4.2	11.8 ± 0.9
10 μg PCBs/kg	1.53 ± 0.56	34.3 ± 3.6	12.6 ± 1.8
100 μg PCBs/kg	1.64 ± 0.24	34.8 ± 2.5	12.8 ± 0.9

[a] N = 10 per dose group (N=8 for controls).

[b] arithmetic mean ± standard deviation

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UPDATE: TOXICOLOGICAL STUDIES OF *CIS*- AND *TRANS*-NONACHLOR IN RATS

Project Leader: Genevieve Bondy, Toxicology Research Division, Food Directorate, Health Protection Branch, Health Canada

Project Team: **(all from Toxicology Research Division unless otherwise indicated):** Michael Barker, pathology; Gerard Cooke, reproductive toxicology; Ivan Curran, molecular toxicology; Santokh Gill, neurotoxicology; Eric Lok, immunochemistry and behavioural toxicology; Rekha Mehta, carcinogenesis and immunohistochemistry; Harvey Newsome (Food Research Division), residue analyses; Olga Pulido, neuropathology; Paul Rowsell, molecular toxicology, Catherine Suzuki, renal toxicology, Helen Tryphonas, immunotoxicology; Technical staff, Toxicology Research Division, Food Research Division.

OBJECTIVES

General:

1. To determine and compare the toxicological effects of *cis*-nonachlor and *trans*-nonachlor in male and female rats.

1998/99:

1. To continue tissue and data analyses from the completed animal study.

DESCRIPTION

The organochlorine pesticide chlordane was used in North America until the late 1980s as a termiticide, as a seed dressing or coating, and as an insecticide on crops, lawns and gardens. Technical grade chlordane is a mixture of over 120 structurally related compounds. The most abundant constituents are *cis*-chlordane, *trans*-chlordane, heptachlor, *trans*-nonachlor, *cis*-nonachlor and α–, β–, and γ-chlordene (Dearth and Hites 1991a). As a result of the widespread usage of chlordane, which has an environmental half-life of 10-20 years (Bennett *et al.* 1974), this toxic and persistent mixture has accumulated in the food chain. This is particularly the case in polar regions, where chlordane-related compounds have been detected in fish and marine mammals at levels comparable to polychlorinated biphenyls (PCBs) and DDT isomers. Oxychlordane, *cis*- and *trans*-nonachlor, and *cis*- and *trans*-chlordane have been detected in three trophic levels of the Arctic marine food chain, including polar bear fat, ringed seal blubber and Arctic cod muscle (Muir *et al.* 1988). Humans have also been exposed to chlordane-related contaminants. In the Arctic, consumption of traditional foods contributes to chlordane exposure (Kuhnlein 1995, Kuhnlein *et al.* 1995, Kinloch *et al.* 1992). *Cis*- and *trans*-nonachlor, oxychlordane and *trans*-chlordane were detected in human breast adipose samples obtained from Bloomington, IN (Dearth and Hites 1991b). *Trans*-nonachlor and oxychlordane were detected in human adipose autopsy samples from six Ontario municipalities in the Great Lakes Basin (Williams *et al.* 1988). Human abdominal adipose was shown to contain chlordane, oxychlordane and nonachlor, in order of increasing concentration, in samples from Japan (Hirai and Tomokuni 1991).

The primary focus of existing toxicological data has been on the potential adverse health effects of the parent chlordane mixture, for which a toxicological profile has been compiled (U.S. Department of Health and Human Services 1994). Comparable toxicity data for *trans*-nonachlor, *cis*-nonachlor or oxychlordane, which are among the most common chlordane-related environmental contaminants and tissue residues, are non-existent. This study addresses the toxicological data gap for *trans*- nonachlor and *cis*-nonachlor, with oxychlordane toxicity to be addressed in a future study. Male and female rats were exposed to *trans*- and *cis*-nonachlor by gavage for 28 consecutive days and multiple toxicological endpoints were examined.

ACTIVITIES IN 1998/99

The animal phase of this research was completed in December 1997. Analyses of tissues and biological samples continued throughout 1998 and part of 1999. The clinical chemistry, hematology, urinalysis and residue analyses data were completed and analysed. A preliminary histopathological assessment was completed. Immunohistochemical analyses of liver and kidney tissues for markers of preneoplastic lesions and cellular proliferation were completed.

Table 1. Uptake of the organic cation tetraethylammonium (TEA) in kidney slices from male rats gavaged with *cis*-nonachlor or *trans*-nonachlor for 28 days.

Dose (mg·kg^{-1})	Test chemical	
	Cis-nonachlor	*Trans*-nonachlor
0	15.57 ± 0.86[a]	17.48 ± 0.76
0.25	15.57 ± 0.65	15.25 ± 1.26
2.5	12.15 ± 0.53[b]	13.19 ± 1.14[b]
25	11.83 ± 0.97[b]	11.98 ± 0.55[b]
P	0.024[c] (-)	0.018[c] (-)

[a] All data are expressed as mean ± standard error for n=4 rats.

[b] Data are significantly different from corresponding controls ($p \leq 0.05$).

[c] Significant trend ($p \leq 0.05$) using Pearson Product Moment correlation. The symbol in brackets indicates the direction of the trend over the dose range 0 to 25 mg·kg^{-1}.

Table 2. Effects of *cis*-nonachlor on total serum immunoglobulins.

FEMALES

Dose (mg·kg^{-1})	Immunoglobulin concentration (ng·mL^{-1} serum) x 10^6				
	IgM	IgG_1	IgG_{2a}	IgG_{2b}	IgG_{2c}
0	1.96 ± 0.30[a]	1.19 ± 0.29	0.52 ± 0.01	0.36 ± 0.14	0.49 ± 0.10
0.25	2.39 ± 0.39	1.56 ± 0.33	0.72 ± 0.10	0.45 ± 0.09	0.61 ± 0.11
2.5	2.19 ± 0.11	1.09 ± 0.16	0.82 ± 0.14	0.35 ± 0.08	0.49 ± 0.05
25	2.68 ± 0.33	2.24 ± 0.62	3.10 ± 1.98[b]	0.57 ± 0.08	1.17 ± 0.59
P	0.157	0.047[c] (+)	0.016[c] (+)	0.102	0.081

MALES

Dose (mg·kg^{-1})	Immunoglobulin concentration (ng·mL^{-1} serum) x 10^6				
	IgM	IgG_1	IgG_{2a}	IgG_{2b}	IgG_{2c}
0	3.94 ± 0.30	1.32 ± 0.29	0.55 ± 0.08	0.54 ± 0.11	0.29 ± 0.06
0.25	4.91 ± 0.51	2.03 ± 0.59	0.91 ± 0.13[b]	1.16 ± 0.66	0.35 ± 0.13
2.5	3.84 ± 0.30	7.91 ± 3.71[b]	1.84 ± 0.43[b]	1.57 ± 0.38	0.59 ± 0.07[b]
25	3.38 ± 0.26	4.03 ± 0.37[b]	1.51 ± 0.22[b]	2.24 ± 0.59[b]	0.59 ± 0.11[b]
P	0.049[c] (-)	0.734	0.157	0.037[c] (+)	0.079

[a] All data are expressed as mean ± standard error.

[b] Significantly different from corresponding control ($p \leq 0.05$) using Dunn's test for pairwise comparisons.

[c] Significant trend ($p \leq 0.05$) using Pearson Product Moment correlation. The symbol in brackets indicates the direction of the trend over the dose range 0 to 25 mg·kg^{-1}.

Table 3. Summary of preliminary pathology findings in the liver and kidneys of rats treated with *cis*- and *trans*-nonachlor.

Test chemical	Liver		Kidneys	
	male rats	female rats	male rats	female rats
cis-nonachlor	• hypertrophy at 0.25 mg·kg^{-1} (zone 3 only; 1/7 rats), hypertrophy and paler and more homogenous cytoplasm at 2.5 mg·kg^{-1} (zone 3 and/or zones 2 and 3; 3/7 rats) and 25 mg·kg^{-1} (zones 2 and 3; 7/7 rats). • anisokaryosis with in-creased nuclear size at 25 mg·kg^{-1} (2/7 rats)	• hypertrophy, paler and more homogenous cytoplasm at 25 mg·kg^{-1} (zone 3 and/or zones 2 and 3; 6/6 rats). • anisokaryosis with increased nuclear size at 25 mg·kg^{-1} (5/6 rats).	• no treatment-related changes	• no treatment-related changes
trans-nonachlor	• hypertrophy at 0.25 mg·kg^{-1} (zone 3; 2/7 rats) and 2.5 mg·kg^{-1} (zone 3; 4/7 rats); hypertrophy, paler and more homogenous cytoplasm at 25 mg·kg^{-1} (zones 2 and 3; 7/7 rats). • anisokaryosis with increased nuclear size at 25 mg·kg^{-1} (4/7 rats)	• hypertrophy, paler and more homogenous cytoplasm at 0.25 mg·kg^{-1} (zone 3 and/or zones 2and 3; 2/7 rats) and at both 2.5 and 25 mg·kg^{-1} (7/7 and 4/4 rats, respectively) • anisokaryosis with increased nuclear size at 2.5 mg·kg^{-1} (2/7 rats) and 25 mg·kg^{-1} (4/4 rats).	• hyperplasia along with rare to occasional necrosis and sloughing of epithelial cells of scattered tubules in the cortex and outer stripe of the outer medulla, at 2.5 mg·kg^{-1} (1/7 rats) and 25 mg·kg^{-1} (3/7 rats).	• no treatment related changes

Table 4. Adipose and liver residues in rats receiving *cis*-nonachlor for 28 days by gavage.

Tissue[a]	Residue[b]	Females				Males			
		0[c]	0.25	2.5	25	0	0.25	2.5	25
Adipose	OXY	0.0 ± 0.0	3.5 ± 0.2	28.6 ± 2.2	326.9 ± 36.7	0.0 ± 0.0	2.7 ± 0.2	13.2 ± 1.6	136.1 ± 9.5
	CIS	0.1 ± 0.0	14.3 ± 3.1	90.5 ± 9.2	868.8 ± 89.4	0.1 ± 0.0	7.6 ± 0.8	42.8 ± 5.1	542.6 ± 99.6
	TRANS	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	1.1 ± 0.3
Liver	OXY	0.0 ± 0.0	0.2 ± 0.0	1.4 ± 0.1	15.6 ± 1.7	0.0 ± 0.0	0.2 ± 0.0	1.3 ± 0.1	12.3 ± 0.4
	CIS	0.0 ± 0.0	0.4 ± 0.1	2.1 ± 0.3	15.8 ± 4.1	0.1 ± 0.0	0.9 ± 0.7	0.9 ± 0.3	11.8 ± 5.7

[a] Data for adipose tissue are expressed as ppm/g oil; data for liver are expressed as ppm/g tissue wet weight. All data are expressed as mean ± SE for 6<n<7 rats

[b] Abbreviations: OXY = oxychlordane; CIS = *cis*-nonachlor; TRANS = *trans*-nonachlor.

[c] *Cis*-nonachlor dose in mg·kg^{-1} body weight/day.

Table 5. Adipose and liver residues in rats receiving *trans*-nonachlor for 28 days by gavage.

Tissue[a]	Residue[b]	Females				Males			
		0[c]	0.25	2.5	25	0	0.25	2.5	25
Adipose	OXY	0.0 ± 0.0	5.9 ± 0.8	48.6 ± 4.5	527.1 ± 40.0	0.0 ± 0.0	5.0 ± 0.3	29.2 ± 16.3	428.2 ± 16.1
	TRANS	0.0 ± 0.0	30.6 ± 5.0	158.9 ± 31.0	3613.7 ± 1022.1	0.1 ± 0.0	13.7 ± 1.1	72.2 ± 6.7	1367.7 ± 98.8
Liver	OXY	0.0 ± 0.0	0.2 ± 0.0	2.4 ± 0.1	24.3 ± 0.9	0.0 ± 0.0	0.4 ± 0.0	3.6 ± 0.3	31.5 ± 1.5
	TRANS	0.0 ± 0.0	0.7 ± 0.1	2.5 ± 0.4	95.7 ± 29.4	0.0 ± 0.0	0.7 ± 0.1	2.2 ± 0.5	57.2 ± 7.4

[a] Data for adipose tissue are expressed as ppm/g oil; data for liver are expressed as ppm/g tissue wet weight. All data are expressed as mean ± SE for 6<n<7 rats, except for females in the 25 mg·kg^{-1} dose group where n = 4.

[b] Abbreviations: OXY = oxychlordane; TRANS = *trans*-nonachlor.

[c] *Trans*-nonachlor dose in mg·kg^{-1} body weight/day.

RESULTS

Study design and general observations made during the animal phase were summarized in Environmental Studies No.75: Synopsis of research under the 1997/98 Northern Contaminants Program (Bondy *et al.* 1999).

Renal function

The following urinalysis endpoints were unaffected by *cis*- and *trans*-nonachlor: volume, protein, osmolality, creatinine, N-acetyl-β-D-glucosaminidase (NAG) and γ-glutamyl transferase (GGT). Transport of the organic anion p-aminohippuric acid (PAH) in kidney slices was unaffected in male and female rats. Transport of the organic cation tetraethylammonium (TEA) was not affected in female rats but was depressed in both *cis*- and *trans*-nonachlor-treated male rats at the 2.5 and 25 $mg \cdot kg^{-1}$ dose levels (Table 1).

Immunotoxicology

Total IgM, IgG_1, IgG_{2a}, IgG_{2b} and IgG_{2c} were measured in serum using sandwich ELISAs and anti-rat immunoglobulin antibodies. Most changes in total serum immunoglobulin levels occurred in male and female rats treated with *cis*-nonachlor (Table 2). In female rats, IgG_{2a} levels were significantly higher than corresponding controls at the 25 $mg \cdot kg^{-1}$ dose level, accompanied by a significant trend towards increased IgG_{2a} over the dose range. A similar trend was observed for IgG_1. In male rats treated with *cis*-nonachlor, serum IgG_1 and IgG_{2c} were significantly higher than corresponding controls at the 2.5 and 25 $mg \cdot kg^{-1}$ dose levels. Serum IgG_{2a} levels in treated rats were significantly higher than levels in control rats at all doses. Serum IgG_{2b} was significantly higher than controls at the 25 $mg \cdot kg^{-1}$ dose level, and there was a significant trend towards increasing IgG_{2b} levels in serum over the dose range. In contrast, there was a significant trend towards decreasing total IgM levels over the dose range tested.

Immunohistochemistry

At necropsy, liver and kidney slices were fixed in formalin for routine paraffin embedding and immunohistochemical analysis of glutathione S-transferase placental form (GSTP), a cellular marker for hepatic preneoplastic cells and lesions, and proliferating cell nuclear antigen (PCNA), a protein expressed preferentially in the nuclei of proliferating cells. Data analyses so far at the highest dose level (25 $mg \cdot kg^{-1}$), indicate that compared to controls (0 $mg \cdot kg^{-1}$), expression of GSTP in individual hepatocytes was increased significantly in *trans*-nonachlor-treated male rats, and in female rats treated with *cis*- and *trans*-nonachlor. Significant elevations of PCNA expressing hepatocytes were observed in *trans*-nonachlor-treated males, and *cis*-and *trans*-nonachlor-treated females. In contrast, in the kidney, PCNA expression, which remained unaltered in females, was increased in both *cis*- and *trans*-nonachlor-treated male rats. These data suggest sex and tissue-specific differences in the preneoplastic and cell proliferative effects of *cis*- and *trans*-nonachlor.

Pathology

The pathology report is preliminary. The changes seen to date in the liver and kidneys of rats treated with *cis*- and *trans*-nonachlor are summarized in Table 3.

Residue analyses

In rats treated with *cis*-nonachlor the primary residues in adipose and liver were *cis*-nonachlor and oxychlordane. In adipose from males and females there was approximately 3-4 times more *cis*- nonachlor than oxychlordane. In the liver, *cis*-nonachlor and oxychlordane levels were similar. Overall, females accumulated more *cis*-nonachlor and oxychlordane in adipose than male rats (Table 4).

In *trans*-nonachlor-treated rats, *trans*-nonachlor and oxychlordane were detected in adipose and liver. In adipose, *trans*-nonachlor was present in greater quantities than oxychlordane, with ratios of *trans*-nonachlor to oxychlordane ranging from 2.5-6.9 between sexes and dose groups. In liver, the ratio of *trans*-nonachlor to oxychlordane was lower, ranging from 0.6-3.9. Female rats accumulated higher residue levels than males, particularly of *trans*-nonachlor (Table 5).

SUMMARY

In the previous synopsis (Bondy *et al.* 1999), toxicity data indicated the following: (1) *trans*- nonachlor was more toxic than *cis*-nonachlor; (2) females were more sensitive to *trans*-nonachlor than males; (3) the liver is a target organ for both *cis*- and *trans*-nonachlor based on organ weights, immunohistochemistry and clinical chemistry; (4) the primary metabolite of both *cis*- and *trans*- nonachlor is oxychlordane. Continued analyses indicated that the kidneys were also affected by *cis*- and *trans*-nonachlor, but that renal changes were gender-specific. Histopathological changes and depressed organic cation transport were confined to male rats, as were the increases in renal cell proliferation. Although increased levels of serum IgG subclasses in rats treated with *cis*-nonachlor indicated potential immunostimulation, additional evidence of enhanced immune responses are required to confirm these results. Further examination of the residue data indicated that residues were higher per gram of adipose tissue in females than in males. Whether or not this difference was due to the mobilization of *cis*- and *trans*-nonachlor into a smaller total body fat pool in females could not be determined from this study because total body fat percentages at necropsy in male and female rats were not measured.

Expected Project Completion Date: Most analyses will be complete in 1999/2000.

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ASSESSMENT OF DIETARY BENEFIT:RISK IN INUIT COMMUNITIES (YEAR 2)

Project Leader: Harriet V. Kuhnlein, Centre for Indigenous Peoples' Nutrition and Environment (CINE), McGill University

Project Team: Harriet V. Kuhnlein, Olivier Receveur and Laurie Chan, CINE; Eric Loring, Inuit Tapirisat of Canada (ITC)

OBJECTIVES

1. To derive quantitative estimates of traditional/country and market food intake among Inuit in five regions (Inuvialuit, Kitikmeot, Keewatin, Baffin and Labrador), representing approximately 50 Inuit communities.
2. To complete databases of nutrient and contaminant contents of traditional/country food as prepared and consumed for quantitative estimates of intake of these items.
3. To define benefits of traditional/country food in terms of nutritional, socioeconomic and cultural significance.
4. To define the levels of dietary exposure to contaminants (Hg, Cd, As, Pb, organochlorines).

DESCRIPTION

This was the second year of a three-year initiative. During the first year, five regional workshops were conducted in which representatives of 39 Inuit communities reviewed the need for the research on traditional Inuit food, and expressed their views on how to best conduct the research. The workshops identified the communities to best represent their regions. The spectrum of traditional/country food resources in each region was identified by season, and the most important foods noted. It was decided to conduct the interview research during early Fall (September-November) and late winter (February-March) to represent the seasons of highest and lowest traditional/country food consumption. During these periods, food samples prepared for consumption were to be collected for analysis of nutrients and contaminants.

The 19 communities identified for participation were Aklavik, Tuktoyaktuk, Paulatuk, Holman, Kugluktuk, Cambridge Bay, Pelly Bay, Baker Lake, Chesterfield Inlet, Rankin Inlet, Resolute Bay, Pond Inlet, Igloolik, Kimmerut, Qikiqtarjuaq, Nain, Hopedale, Makkovik, and Rigolet. Research agreements between each community and CINE were prepared and negotiated by the CINE Field Coordinator (Dr. O. Receveur). A representative from ITC (Mr. E. Loring) assisted with information sharing with the Regional Inuit Organizations, Hamlet Councils, Inuit Women's Association, the Hunters and Trappers Associations, and the Regional Health Boards. Science licenses were obtained from the Aurora Research Insitute and Nunavut Research Institute.

ACTIVITIES IN 1998/99

During 1998/99, data collection proceeded following training workshops at CINE for the six project field coordinators. These coordinators were research-trained health specialists, usually dietitians, who worked throughout the data and food collection phase in each of the communities. Community residents identified by the Hamlet Council or Hunters and Trappers Association office were trained in the communities for completing the interviews in collaboration with the project field coordinators.

In each community, a random sample of 10% of households was drawn. In each household, two adults and one adolescent (if available) were invited to participate. The survey instruments included 24-hour recalls, a repeat 24-hour recall on a subsample of respondents, traditional/country food frequency records targeting the months of June-August 1998 and December-February 1999, and seven-day traditional/country food records for the months of October 1998 and March 1999. A short socioeconomic questionnaire was also completed. During the winter interview period, qualitative food use data was augmented with a card-sort exercise that ranked respondents' perceptions of the health benefits of commonly used traditional/country and market food. Height and weight measures were also requested. A summary of the number of interviews completed is given in Table 1.

Food samples were identified for collection when they were commonly consumed in the communities. The research coordinators in each region guided sample

Table 1. Assessment of Dietary Benefit:Risk in Inuit Communities. Summary of Collection of Individual Dietary Data, Card Sorts and Anthropometric Data.

			Number collected											
Region	**Site**	**Community**	**Food frequency**		**7-day food records**		**24hr recalls**		**Repeated 24hr recalls**	**Card sorts**	**Reported Heights**		**Reported Weights**	
			Fall	Winter	Fall	Winter	Fall	Winter	(Winter)	(Winter)	Fall	Winter	Fall	Winter
Inuvialuit	1	Aklavik	54	51	53	43	53	51	11	10	28	37	23	42
	2	Tuktoyaktuk	31	66	2	16	31	64	10	10	25	52	22	52
	3	Paulatuk	40	57	34	46	40	57	16	10	14	13	6	12
		Total:	**125**	**174**	**89**	**105**	**124**	**172**	**37**	**30**	**67**	**102**	**51**	**106**
Kitikmeot	4	Holman	51	60	5	1	37	55	10	3	26	18	23	13
	5	Kugluktuk (Coppermine)	51	59	9	0	51	59	6	8	37	40	33	37
	6	Cambridge Bay	42	59	21	0	40	58	10	4	28	48	31	46
		Total:	**144**	**178**	**35**	**1**	**128**	**172**	**26**	**15**	**91**	**106**	**87**	**96**
Kivalliq	8	Baker Lake	59	62	0	3	52	59	12	14	23	15	22	15
	9	Chesterfield Inlet	59	56	42	36	59	56	11	11	34	31	35	17
	10	Rankin Inlet	60	59	14	8	60	57	0	0	14	34	15	33
		Total:	**178**	**177**	**56**	**47**	**171**	**172**	**23**	**25**	**71**	**80**	**72**	**65**
Baffin	11	Resolute Bay	40	40	28	23	40	36	11	6	27	28	30	29
	12	Pond Inlet	55	58	54	30	55	54	3	0	31	28	39	24
	13	Igloolik	50	59	48	57	50	59	4	5	23	27	26	26
	14	Kimmirut (Lake Harbour)	62	59	9	52	62	58	19	20	35	43	37	52
	15	Qikiqtarjuaq (Broughton Island)	60	51	18	19	59	51	10	8	16	7	21	12
		Total:	**267**	**267**	**157**	**181**	**266**	**258**	**50**	**39**	**132**	**133**	**153**	**143**
Labrador	16	Nain	46	39	25	23	46	39	9	10	35	31	34	32
	17	Hopedale	50	47	48	24	50	47	3	2	28	39	35	37
	18	Makkovik	66	71	62	71	66	71	20	4	47	38	45	35
	19	Rigolet	53	48	51	46	51	47	4	1	34	30	29	29
		Total:	**215**	**205**	**186**	**164**	**213**	**204**	**36**	**17**	**144**	**138**	**143**	**133**
		Grand Total:	**929**	**1001**	**523**	**498**	**902**	**978**	**172**	**126**	**505**	**561**	**506**	**546**

collections that were stored and shipped to the CINE laboratory. In all, 212 food samples were collected which represented 45 commonly consumed food parts/species for which nutrient analyses were needed for the dietary data evaluations.

Following these collections, work in the laboratory became intensive. Samples were portioned for the various analyses, prioritized for the extent of reported use in the 24-hour recalls, and also by the most significant nutrients and contaminants. This work is continuing and is now augmented with vitamin analysis in collaboration with Health Canada. In the CINE laboratory, analyses underway include proximate composition (fat, protein, moisture, ash, fibre (if relevant), energy, minerals (Fe, Ca, Zn, Cu, Mn, Mg, Se, Na, K), and fatty acids. Methods have been developed for the efficient analysis of vitamins A and D. Heavy metals (As, Cd, Hg, Pb) and organochlorines (PCBs, selected pesticides and toxaphene) are being analysed within the Northern Contaminants Program QA/QC guidelines.

DISCUSSION/CONCLUSIONS

The first and second phases of this project were successful in developing excellent cooperation among CINE research team members, ITC, regional Inuit Associations, and community Hamlet Offices and HTA Offices. The extent of interview data and food sample collection was extraordinary and exceeded expectations. The regional research coordinators and the community interviewers are to be congratulated for their efforts.

The extent of interviews completed and food samples collected will lead to a thorough report and understanding of the various benefits and risks of Inuit diets. During the final year of the project, the laboratory work will be completed.

Expected Project Completion Date: Laboratory work for nutrients and contaminants for the food samples is expected to be completed mid-Fall 1999. Databases will then be constructed for analyses of the dietary data, which will then form the basis for the draft report to be circulated in 2000. The process of discussing results with communities will be initiated and is expected to carry over into the year 2001.

TOXICOLOGY OF MERCURY AND SELENIUM IN RINGED SEAL TISSUES (YEAR 2)

Project Leader: Centre for Indigenous Peoples' Nutrition and Environment (CINE) McGill University

Project Team: Laurie H.M. Chan, CINE, McGill University; Frank Iverson and Catherine Suzuki, Health Protection Branch, Health Canada

OBJECTIVES

The overall objective of this project is to study the interactions between mercury (Hg) and selenium (Se) in ringed seal tissues and elucidate the potential protection of methylmercury (MeHg) toxicity by Se in the traditional diet.

Specific objectives of this project are:

1. to isolate and characterize the different species of Hg and Se in muscles, livers, brain and kidneys of ringed seals.
2. to conduct an animal feeding experiment to study the toxicity of co-ingestion of the biological Hg and Se found in seal meat using a rat model.

DESCRIPTION

The chemical form of the Hg-Se complex in ringed seals has never been characterized. Tiemannite (mercury selenide) granules were identified in the livers of two cetaceans *Ziphius cavirostris* and *Tursiops truncatus* (Martoja and Berry 1980). This Hg-Se complex, though never characterized, was suggested to be the last stage of the detoxification process through the demethylation of Hg, leading to the fossilization of Hg and Se in the form of non-biodegradable compounds. A stable Hg-selenoprotein was reported in dolphin livers (Palmisano *et al.* 1995, Cavalli and Cardellicchio 1995). Similarly, Caurant *et al.* (1996) suggested that in pilot whale liver, Se is involved in promoting the binding of Hg with less critical proteins after the formation of Se-trisulphide groups. Magos (1991) described an unstable adult of *bis*-methylmercury selenide in rodents. Yoneda *et al.* (1997a, 1997b) suggested the Hg-Se in human serum may be a heparin-binding protein.

It has been over thirty years since Parizek and Ostadalova (1967) described the protective effect of selenite against mercuric chloride intoxication. The interaction between Hg and Se has been the object of intensive research. The role of Se, particularly the biological Se in the protection against MeHg, remains unquantified or even uncertain (Magos 1991).

ACTIVITIES IN 1998/99

Organ tissues (brain, liver, kidney and muscle) from six ringed seals were obtained from Dr. Michael Kwan of the Makivik Research Centre. Hg and Se concentrations were measured in the seal liver, kidney, muscle, cerebrum and cerebellum. Among those tissues, seal liver was found to have the highest Hg and Se levels, which are 5.99 and 3.41 $\mu g \cdot g^{-1}$ respectively (Table 1). The percentage of the Hg and Se in the cytosol or the supernatant also varies among different tissues.

Additional seal livers (about 4 kg) were made available from Dr. Lyle Lockhart of the Department of Fisheries and Oceans. It was decided to concentrate the extraction on the liver samples. Eight different buffers were tested to extract Hg and Se in the pellet. Results are shown in Table 2. The highest extraction rate of 60% for both Hg and Se was obtained with 0.2 M Na_2HPO_4-NaH_2PO_4, pH 7.0 + 4% SDS.

The seal liver extract was eluted on a gel filtration column (Sephadex G-75 column) at 0.8 $mL \cdot min^{-1}$ and fractions were collected every 3 mL. Hg and Se were measured for each fraction using ICP-MS. Two major peaks were identified at 21 min. and 101 min. that correspond to approximately MW 66,000 D and MW 15,000 D (Figure 1). Hg:Se molar ratio for the fractions of the first peak was close to 1, and it accounted for over 50% of the Hg and Se in the seal liver samples. We decided to isolate this fraction that contains Hg and Se for the animal feeding experiment.

The Hg-Se complex in the first fraction was isolated from the liver extract by dialysis (MW cut off at 30,000 D) using a Millipore Minitan System for 8 hours. Removal of the second peak was confirmed using gel filtration chromatography.

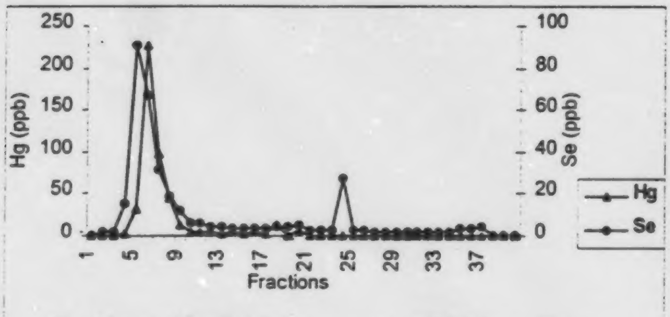

Fig. 1 Hg and Se distributions among FPLC fractions- Seal liver extract

Figure 1. Hg and Se distributions among FPLC fractions - Seal liver extract

The animal feeding experiment will be carried out at the animal facilities located in the Banting Building of Health Canada. Only tissue samples collected at the time of the necropsy will be sent to CINE for Hg speciation and analysis.

Groups of male rats (n = 10 per group) will be administered one of the following by gavage administration at three dose levels (Table 3) for 14 days:

Hg-Se complex;
MeHg;
MeHg + Se; or
Se

Body weight, food and water consumption will be monitored daily throughout the study. Prior to dosing, midway through, and again at the conclusion of the study, animals will be transferred to metabolic cages for 24 hour urine collections. At the end of the 14-day dosing regimen, all rats will be necropsied. The following endpoints will be measured:

- organ weight
- clinical chemistry (serum and urine)
- hematology
- histopathology
- Renal toxicity endpoints:
  - Glutathione and catalase concentrations
  - Urinalysis (enzymes, proteins, osmolality)
  - Organic ion transport
  - Gene transcription analyses of enzymes
  - Preneoplastic lesions
- Neurotoxicity endpoints:
  - Markers of apoptosis
  - Neurobehavioural parameters
- Hepatotoxicity endpoints:
  - PKC
  - Glutathione and catalase concentrations
- Hg and Se quantification and speciation in various tissues

The animal feeding experiment will be completed by the Fall of 1999. In the last phase of the project, we will characterize the speciation of Hg and Se in the isolated complex as well as in other ringed seal tissues including brain, kidneys and muscle.

Expected project completion date: March 31, 2000.

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Table 1. Hg and Se concentration and their distribution in seal tissues (Mean±SD)

Tissue Type	HG (µg/g)	Distribution (%)		Se (µg/g)	Distribution		Hg:Se molar ratio
		Supernatant	Pellet		Supernatant	Pellet	
Liver	5.9917 ± 2.0-514	19.7 ± 7.67	80.3 ± 7.67	3.4148 ± 0.6071	19.6 ± 6.36	80.4 ± 6.36	0.69
Kidney	0.7021 ± 0.3091	59.3 ± 7.01	40.7 ± 7.01	0.5748 ± 0.1188	42.6 ± 6.47	57.4 ± 6.47	0.48
Muscle	0.2392 ± 0.1469	11.0 ± 2.44	89.0 ± 2.44	0.0201 ± 0.004	53.0 ± 1.05	47.0 ± 1.05	4.7
Cerebrum	0.0747 ± 0.0368	18.6 ± 3.59	81.4 ± 3.59	0.0297 ± 0.0062	68.7 ± 5.64	31.3 ± 5.64	0.99
Cerebellum	0.0551 ± 0.0193	20.1 ± 4.31	79.9 ± 4.31	0.472 ± 0.0118	65.3 ± 2.28	34.7 ± 2.28	0.46

100 mM Tris-HCl pH 7.6, 1:1 (tissue:buffer, w/v) homogenize, centrafuge at 10,000 g for 30 min. n=4.

Table 2. Hg and Se Extraction using 8 different Buffers (%)

Buffer Solution	Hg	Se
1% NaC1	5.4	1.8
0.2 M Na_2HPO_4-NaH_2PO_4 pH 7.0	6.2	1.3
0.2 M Ammonium Acetate	4.0	9.2
0.2 M Na_2HPO_4-NaH_2PO_4 pH 7.0 + 1% SDS	25.5	30.0
0.2 M Ammonium Acetate + 4% SDS	40.0	44.0
0.2 M Na_2HPO_4-NaH_2PO_4 pH 7.0 + 2% Triton X-100	8.3	1.2
0.2 M Ammonium Acetate + 1% SDS	4.5	10.5
0.2 M Na_2HPO_4-NaH_2PO_4 pH 7.0 + 4% SDS	60.0	60.0

Table 3. Summary of Animal Experiments

Treatment	Dose	Groups	# Animals per group
Hg+Se complex	1 mg Hg/kg		10
	2 mg Hg/kg		10
	4 mg Hg/kg		10
MeHg	1 mg Hg/kg		10
	2 mg Hg/kg		10
	4 mg Hg/kg		10
Se	0.4 mg Se/kg		10
	0.8 mg Se/kg		10
	1.6 mg Se/kg		10
MeHg + Se	1 mg Hg/kg	0.4 mg Se/kg	10
	2 mg Hg/kg	0.8 mg Se/kg	10
	4 mg Hg/kg	1.6 mg Se/kg	10
Controls			10
Quality control			2

USE OF PBTK MODEL FOR RISK ASSESSMENT OF EXPOSURE TO MIXTURES OF ORGANOCHLORINES IN TRADITIONAL FOOD (YEAR 2)

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OBJECTIVES

The overall objective of this project is to develop a framework for assessing the potential health risks to the Arctic Inuit communities associated with the dietary intake of mixtures of chemical contaminants in traditional food.

DESCRIPTION

Risk assessment should ideally be based on detailed knowledge of the relationships between external and internal dose, organ levels, and their relation to toxic symptoms in humans. However, human data on these toxicokinetic parameters for environmental pollutants originated mainly from individuals or small populations accidentally exposed for short periods of time to relatively high contaminant levels, but with an unknown total body burden. Therefore, assessment of the risk associated with exposure to low levels of environmental pollutants has had to depend largely on data from animal experiments.

The use of physiologically based toxicokinetic (PBTK) modeling is a scientifically sound, mechanistic tool that has increasingly been used in health risk assessment procedures for the conduct of extrapolations essential for reducing the uncertainties (Krishnan and Andersen 1994). Moreover, the recent validation of the usefulness of a physiological modeling approach in simulating the kinetics and dynamics of chemical mixtures, by accounting for the multiple chemical interactions (Pelekis and Krishnan 1995, 1997, Tardif *et al.* 1997) has given way to the development of an interaction-based risk assessment approach.

ACTIVITIES IN 1998/99

The first phase of this project was funded by the Northern Contaminants Program (NCP) in November, 1997. Phase 2 of the project was approved for funding in May, 1998. Based on the dietary intake data collected from Broughton Island in 1988 (Chan *et al.* 1997), a mixture of organochlorines was designed to contain hexachlorobenzene, α–, β–, γ– HCH, *oxy-*, *cis-* and *trans*-chlordane, *cis-* and *trans*-nonachlor, dieldrin, DDE, DDT, mirex, toxaphene, and PCB congeners (28,32,101,99,118,105,153,128,138,156,187,183,180,199). Based on the toxicological dose equivalency of human studies and the LOEL ('lowest observable effect level') and NOEL ('no observable effect level'), the dosages were decided to be 10X, 100X, and 1000X the mean daily intake level. Chemicals of highest purity were purchased from a commercial supplier and the mixture was prepared in hexane at the CINE lab and shipped to Health Canada for the feeding experiment. The mixture in hexane was added to corn oil to make up the desired dosage. Concentrations of the organochlorine (OC) dose in the corn oil were confirmed by chemical analysis using GC-MS. Four groups of 12 female rats were administered the mixture in corn oil by gavage (three dose levels plus controls) for 28 days. The animals were necropsied at the end of the experiment and OC levels in liver and adipose tissue are being used to validate the mixture in the PBTK model. Preliminary results of the toxicity test were presented in the 31st Annual Symposium of the Society of Toxicology of Canada (Suzuki *et al.* 1998). There were no overt signs of toxicity in any of the dose groups throughout the study, that is, no changes in body weights, food or water consumption. The only observed clinical chemical change was an increase in serum cholesterol in the 1000X dose group. At the highest dose, the mixture exhibited mixed-type microsomal enzyme induction characteristics with increases in ethoxyresorufin *o*-deethylase, methoxyresorufin *o*-demethylase, pentoxyresorufin *o*-deethylase, benzyloxyresorufin *o*-dealkylation, aminopyrine demethylase and coumarin 7-hydroxylase activities. These changes were accompanied by increases in microsomal protein and percent liver weight per body weight.

Concentrations in the lipids, liver and blood of the rats were measured at the CINE lab and the data were used in PBTK modeling.

A steady-state model for organochlorine contaminants has been developed based on the PBPK equations and parameters. The central equation of this steady-state model is as follows:

$$C_t = C_a \times P_t (1 - E)$$

Where C_t = steady-state tissue concentration; C_a = steady-state blood concentration; P_t = tissue:blood partition coefficient; and E = hepatic extraction ratio, calculated as hepatic clearance divided by liver blood flow rate.

Based on the data on the lipid and water levels in liver tissue and blood, a P_t of 12 for the rodents was calculated. With the knowledge of the C_a measured in the feeding experiments and the numerical value of the liver blood flow rate in the rats (0.912 $L \cdot hr^{-1}$), C_t values were predicted. Hepatic clearance was calculated by dividing the dose administered during the Health Canada studies with the measured C_a values. Subsequently, using the values of hepatic clearance, liver blood flow rate and liver:blood partition coefficient, the liver concentration of organochlorines was calculated from blood concentration data. This aspect is important for conducting the risk assessment approaches based on tissue dose of organochlorines, and for providing a basis for predicting tissue dose in humans for whom blood concentration data have been collected. The predicted liver concentration data were comparable with those of measured liver concentrations for several organochlorine substances (Table 1).

Table 1. Predicted and measured organochlorine concentrations in livers of rats.

Substance	**Liver concentration ($\mu g \cdot L^{-1}$)**	
	Measured	**Predicted**
Hexachlorobenzene	168.65	153.7
trans-nonachlor	88.4	99.5
p,p'-DDE	272.4	214.9
cis-nonachlor	11.0	8.3
PCB-183	31.8	27.3
PCB-101	12.9	21.6
PCB-99	62.7	83.2
PCB-118	90.0	111.3
PCB-180	33.91	71.25

These results have been presented at a recently held conference in the form of a poster (Emond *et al.* 1999).

The preceding calculations were performed using a central value for a typical rat, whereas the experimental values showed some variability. In order to account for the variability and uncertainty in the measures, a methodology has been developed using the program, Analytica. We have constructed the above steady-state model to account for variability in parameters and uncertainty in estimates in the prediction process.

Current work involves the use of this modeling framework to analyse human data and use them to perform scientifically sound risk assessments for the contaminants investigated in the present study.

The results from the second major experiment conducted at Health Canada have also been used in validating or refining model parameters. Such procedures are essential before using the PBTK models and parameters for estimating the internal doses associated with the NOAEL. The adipose tissue concentration data from the second study have been used for validating the adipose tissue:blood partition coefficients, predicted from lipid composition data of both matrices. For the middle dose group the experimental data and predictions are shown in Table 2.

Table 2. Comparison of simulated and experimental concentrations of organochlorines in rats.

Organochlorine	Simulated ($ng \cdot g^{-1}$)	Experimental ($ng \cdot g^{-1}$)
PCB-32	80	35.1
PCB-28	220	158.1
PCB-101	340	334
PCB-99	920	929.6
PCB-118	840	1278.2
PCB-153	1660	2514.3
PCB-105	120	159
PCB-138	1580	2023.6
PCB-187	260	259.4
PCB-183	160	191.1
PCB-128	80	74.7
PCB-156	N/A	76.2
PCB-180	620	558.3
PCB-199	20	12.2
α-HCH	480	3586.4
HCB	1860	6744.7
β-HCH	20	N/A
γ-HCH	160	73.2
oxychlordane	3760	7505.1
trans-chlordane	N/A	85
cis-chlordane	40	60.8
trans-nonachlor	2020	2730.9
DDE	10020	17642.8
dieldrin	1740	2216.3
cis-nonachlor	220	422.3
DDT	4860	4452.7
Mirex	120	118.6

N/A = not available.

In the above simulations, an average value for rats was used. Currently, calculations are being conducted for individual rats. This phase will account for inter-animal variability using Analytica, on the basis of rat-specific body weight information to be provided by Health Canada researchers. The refined steady-state equations and PBTK models will then be used for estimating the internal dose associated with NOAEL, for refining the Tolerable Daily Intake (TDI) values for the contaminants of concern.

The final phase of the project (1999-2000) will involve using the developed model for:

Assessment of acceptable human exposure dose:

The PBTK model that simulates the AUC_{liver} that corresponds to NOAEL determined in the rat will be scaled to a human.

Assessment of health risks to Inuit populations exposed to the chemical mixture in their diet:

The assessment of the potential risks to the Inuit populations exposed to these organochlorine compounds will be performed using two sets of data: (i) the population distribution data on the dietary intake of the chemicals in the mixture; and (ii) concentrations in maternal/cord blood reported by the Government of Northwest Territories (GNWT) cord blood study.

Expected project completion date: March 31, 2000.

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EFFECTS OF PRENATAL EXPOSURE TO ORGANOCHLORINES AND MERCURY ON THE IMMUNE SYSTEM OF INUIT INFANTS

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OBJECTIVES

The main objective of this research project is to examine the effects of prenatal and postnatal exposure to organochlorine compounds (OCs) and mercury on the immune system of Inuit infants, from birth to 12 months of age. The specific objectives include:

1. Assessment of prenatal and postnatal exposure to OCs and mercury
2. Measurements of immunological parameters: humoral immunity, cellular immunity
3. Assessment of vitamin A status.

DESCRIPTION

Contaminants and infectious diseases in the Arctic

The contamination of the arctic aquatic food chain by organochlorine compounds (OCs) has been documented during the last decade (Barrie *et al.* 1992, Thomas *et al.* 1992, Lockhart *et al.* 1992, Muir *et al.* 1992). In spite of regulatory actions adopted since the late 1970s in North America and Western Europe to limit their emission into the environment, these compounds are still being released because of improper storage and disposal and due to their ongoing use in other parts of the world. Once emitted into the environment at mid- and lower latitudes, OCs reach the Arctic via long-range atmospheric and oceanic transport (Barrie *et al.* 1992). High lipophilicity and poor biodegradability lead to their bioconcentration in fatty tissues of organisms. Biomagnification also occurs through the arctic aquatic food chain, resulting in relatively high levels of contaminants being found in top predator species (polar bear, beluga, seal) (Thomas *et al.* 1992, Lockhart *et al.* 1992, Muir *et al.* 1992, Norstrom *et al.* 1988).

Mercury is ubiquitous in the environment. The primary source is from degassing of the earth's crust especially in connection with geothermal activities (Lindqvist *et al.* 1991). Although a minor portion is of anthropogenic origin, it may contribute to the global level and give rise to local pollution when it enters into lakes and rivers. Inorganic mercury compounds from natural degassing solubilization or industrial waste are methylated in the aquatic environment, and methylmercury is introduced into the oceanic food chains and biomagnified (Jensen *et al.* 1997). Consequently, exposure to methylmercury is most important to people in the Arctic.

For cultural and economical reasons, the Inuit from Arctic Quebec rely heavily on marine foods for their subsistence. Their large consumption rate of sea mammal fat, in particular ringed seal and beluga, leads to body burdens of various OCs exceeding those of southern Quebec populations by factors varying between 2 and 10 (Dewailly *et al.* 1989, 1992, 1993, 1996, Ayotte *et al.* 1997).

The relationship between exposure to organochlorines and mercury and the incidence of infections is at this time hypothetical but it is based on the immunotoxic properties of the contaminants which in turn could play a role in the unusually high incidence of infectious diseases in the northern communities. The high incidence of infectious diseases in native infants and children from Nunavik, in particular meningitis, bronchopulmonary and middle ear infections, has been known for many years (Duval 1982, Dufour 1988, Proulx 1988).

The latter is of special concern since approximately 25% of school age Inuit children suffer some kind of hearing loss (Julien 1987).

Immunotoxic properties of contaminants

Several OCs display immunotoxic properties in both laboratory animals and humans, the most potent being substances structurally related to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) such as non- and mono-*ortho* chloro-substituted PCBs as well as 2,3,7,8-chloro-substituted PCDD/Fs. These molecules can bind to the Ah receptor (Safe 1990) and the ligand-receptor complex triggers the expression of genes which are involved in cell proliferation and differentiation (Whitlock 1991). In almost all animal species tested, including primates, PCDD/Fs and PCBs produce myelosuppression, immunosuppression, thymic atrophy, and inhibition of immune complement system components (NRC 1992). Exposure to TCDD during pre- and/or postnatal life results in more severe effects than if the chemical is administered during adult life and in some species may be a prerequisite for immunosuppression (Vos and Luster 1989, Hoffman *et al.* 1986). In fact, available evidence in laboratory animals suggests that the maturation of the immune system is especially vulnerable to the adverse effects of dioxin-like compounds, chlordane, hexachlorobenzene, polycyclic aromatic hydrocarbons and possibly endocrine disrupting compounds such as DDT and kepone (Barnett *et al.* 1987, Holladay *et al.* 1996). In children and young adults accidentally exposed to PCBs and PCDFs in Taiwan ("Yu-Cheng disease"), serum IgA and IgM concentrations as well as percentages of total T cells, active T cells and suppressor T cells were decreased compared to values in age- and sex-matched controls (Chang *et al.* 1981). The investigation of delayed type hypersensitivity responses further indicated that cell-mediated immune system dysfunction was more frequent among patients than controls. Infants born to Yu-Cheng mothers had more episodes of bronchitis or pneumonia during their first 6 months of life than unexposed infants from the same neighbourhoods (Rogan *et al.* 1988). The authors speculated that the increased frequency of pulmonary diseases could result from a generalized immune disorder induced by transplacental or breast milk exposure to dioxin-like compounds, more likely PCDFs (Rogan *et al.* 1988). Eight to 14 year-old children born to Yu-Cheng mothers were recently shown to be more prone to middle-ear diseases than matched controls (Chao *et al.* 1997).

Organic or inorganic mercury possess cytotoxic activities for cellular components of immune system in several species of rodents. Methylmercury, a form of organic mercury, can alter non-specific defense mechanisms, such as inhibition of natural killer (NK) cell's activity in rats and mice. Also, it decreases the expression of certain activation markers of T cells (HLA-Dr, IL-2R) (NRC 1992). Moreover, it has been well demonstrated that methlymercury can affect the functions of B cells and therefore reduce the humoral mediated response (Daum *et al.* 1993). Exposure to inorganic mercury induces allergies and autoimmune problems in hypersensitive individuals.

Immunologic parameters

a) Antibody response following vaccination

Acquired immunity produces a very specific response to a particular microorganism or other type of challenge. It involves mainly the activation of lymphocytes and production of antibodies. Environmental toxins may affect acquired immunity and a broad evaluation of the competence of the response is suitable to draw a better picture of their effect. The development of disease represents the ultimate end point in evaluation of immune suppression. Antibody response to vaccination is an intermediate marker of the competence of the adaptive immunity to infections. Vaccination programs include essentially three types of products: killed vaccine (influenza, whole cell pertussis, inactivated polio), protein conjugated or protein based vaccine (Haemophilus influenza type b, diptheria, tetanus, acellular pertussis vaccine, hepatitis B) and attenuated live virus (measles-mumps-rubella, varicella, BCG). Antibody response to conjugated Haemophilus influenza type b (Hib) is of great interest. Hib vaccine is important in Inuit children because, prior to immunization, Hib was the most frequent cause of bacterial meningitis in Inuit children which was 5-10 times more frequent than in white children (Ward *et al.* 1986).

To evaluate humoral response to Hib-conjugated vaccine, two threshold values have been set: anti-PRP (polyribosilribitol phosphate, a capsule polysaccharide) antibody titer = 0.15 $\mu g \cdot mL^{-1}$ is indicative of immediate protection against Hib, whereas a titer greater than 1.0 $\mu g \cdot mL^{-1}$ was found to protect for a longer term (Ward *et al.* 1994).

b) Complement C' system

The complement (C') system is crucial in young children, since acquired immunity is not completely developed, and therefore C' plays an important role in natural immunity against infectious agents. Deficiency of many of the C' components is associated with increased susceptibility to infections, generally of the upper respiratory tract. The effects of exposure to organochlorine compounds studied in a murine model were: a dose-dependent increased susceptibility to Streptococcus pneumoniae infection, with decreased C3 levels and a lowered total C' hemolytic activity (White *et al.* 1986).

c) Cytokine production by Th1/Th2 cells

Organochlorines and metal ions could modulate the production of Th1/Th2-type cytokines. Some studies used leukocytes exposed *in vivo* to metal ions and tested *in vitro* for cytokine synthesis and secretion. These studies demonstrated that in mice, Hg inhibits the *in vitro* production of IFNα, IFNβ and TNFα by macrophages and induces a dose and time-dependent increase in IL-1 activity (Ellermann-Eriksen *et al.* 1994, Zdolsek *et al.* 1994). High blood levels of IL-4 and IgE and low levels of IFNγ have been observed in animal studies involving treatment with Hg (Heo *et al.* 1996). Occupational exposure of humans to inorganic Hg did not result in a significant variation of the immune response in terms of *in vitro* production of IL-1 and TNFα, whereas a prolonged low level exposure decreased TNFα concentrations (Langworth *et al.* 1993). Along with their effects on Th1/Th2-type cytokines, organochlorines and metal ions are known to alter B-cell activity and to impair host resistance to several bacterial and viral infections (Heo *et al.* 1996). In animals, Hg increased by 100-fold the virus titers following infection with herpes simplex virus 2 (HSV-2) and increased by two-fold the number of macrophages in the heart of mice infected with myocardic coxsackievirus B3 (CB3) (Ellermann-Eriksen *et al.* 1994, Ilback *et al.* 1996). Plasma levels of IFNγ in exposed animals were higher than in infected non-Hg-treated mice. To our knowledge, no data are available for humans. Both IFNγ and TNFα are known antiviral cytokines (Zinkernagel 1993); IL-4 enhances IgG1 and IgE, but reduces IgM productions (Ada 1993); IL-10 down-regulates Th1-cytokines and inhibits IFNγ production (Fiorentino *et al.* 1989).

High levels of organochlorines and metal ions in blood and tissues are frequently related to fish intake. Fish oil-supplemented diets (omega-3 (w3)-rich) have generally been shown to reduce plasma levels of some cytokines. Most human studies have shown decreased plasma levels or diminished production of IL-1 and TNFα while omega-3 fatty acids increased the production of these cytokines in mice (Hardardottir *et al.* 1992, Blok *et al.* 1996). We conclude that both contaminants and omega-3 fatty acids perturb the balance between Th1 and Th2-type cytokines, and impair host resistance to infections. IL-1, IL-2, IL-4, IL-6, TNFα and IFNγ have been repeatedly associated with these changes and will be measured in the present study.

Vitamin A status

Vitamin A influences the expression of over 300 genes and thus plays a major role in cellular differentiation, including that of cells related to immune response (Sommer *et al.* 1996, Semba 1994). Results from different animal and human studies vary, however, almost all studies revealed that lymphopoiesis and/or maturation of lymphocytes are altered (generally reduced) in vitamin A deficiency (Sommer *et al.* 1996, Olson 1994, Semba *et al.* 1993). Vitamin A could increase frequency, severity, and duration of infections. Lower respiratory disease was associated with vitamin A deficiency in many cross-sectional clinic and population based studies. Also, otitis was among the first infections to be associated with vitamin A deficiency in human (Sommer and West 1996, Bloem *et al.* 1990, Semba 1994).

Clinical evidence of vitamin A deficiency has not been reported in Arctic populations, however, dietary intakes of this vitamin, for some Inuit, have been shown to be below recommended dietary intakes. Knowing that vegetables and dairy products containing vitamin A are not consumed in sufficient amounts by the Inuit, daily vitamin A intakes among the Inuit from Nunavik were calculated on an annual basis. Total daily intakes of women aged 18-39 was 2314 U.I., while the recommended daily intakes for this group of age is 2664 U.I. Some food items are consumed on a few occasions during a specific season but contribute almost all of the nutrient intake. This is the case for the consumption of ringed seal liver which is the main source of vitamin A in the traditional diet. Although vitamin A requirements appear to be fulfilled by seal liver consumption, this seasonal contribution might not provide the necessary dose over the entire year (Santé Quebec 1992). Furthermore, laboratory experiments indicate that OCs exposure can modulate vitamin A status. The hepatic vitamin A content was significantly reduced in both male and female rats following exposure to some PCB congeners: CB-77, CB-126 and CB-153 (Hakansson *et al.* 1994).

Overview of the research protocol and the laboratory methods

This study is nested in the ongoing U.S. National Institute of Environmental Health Sciences (NIEHS) neurodevelopmental cohort study, and will involve approximately 150 Inuit mothers and their newborns from Nunavik. Mothers are recruited during pregnancy. It investigates possible detrimental effects on the immune system of Inuit infants which may be induced by prenatal and postnatal (breast-feeding) exposure to persistent environmental contaminants such as organochlorine compounds. These substances accumulate in the body of Inuit women in part due to their consumption of sea mammal fat and can be transferred to the fetus during pregnancy and to the infant during breast-feeding. Immune system function will be evaluated using several parameters: 1) the level of antibody produced by the infant following Haemophilus influenza immunization; 2) the level of proteins which protect the infant against bacterial infections (complement system) before its immune system is fully developed; and 3) the level of chemical messengers (cytokines) which enable the various cells of the immune system to communicate with each other, thereby maintaining its proper function and assuring the protection of the infant against bacteria, parasitic and viral infections.

It is important to evaluate vitamin A status in our cohort to find out if it is associated with contaminants as well as with infectious diseases. Therefore, retinol concentrations will be measured in maternal and cord blood samples. In order to assess exposure to contaminants, concentrations of OCs and mercury are obtained through cord blood analyses and for those breast-feeding, the concentration of contaminants is documented through breast milk analysis. Organochlorines, mercury and vitamin A are also measured in a peripheral blood sample collected from infants at 6 months of age.

All immunological parameters are measured during the first 12 months of life. We evaluate anti-Hib response in Inuit infants at 6 months of age. Given the crucial importance of the C' system in early infancy, we investigate C' abnormalities: the initial test is the measurement of serum total hemolytic C' expressed in 50% hemolytic units (CH50). A normal CH50 generally indicates integrity of the C' system. In the event that low CH50 titers are observed, levels of C3 and C4 components is also carried out to determine from which of the alternative or the classical pathway originates the defect in the C' system. Th1 cytokines (IL-2, IFNγ and TNFα) and Th2 cytokines (IL-4, IL-6 and IL-10) is measured in all plasma collected, at delivery in the maternal blood and fetal blood, as well as in infant blood at 6 months of age.

ACTIVITIES IN THE FIRST YEAR 1998/1999

From April 1 to mid-October 1998, activities were primarily focussed on refining the laboratory protocol. This study requires conducting new laboratory procedures at the Puvirnituk hospital. Some analyses on cord blood samples obtained at the delivery need to be performed within 2 hours of collection. In June 1998, after consultation, the laboratory technicians at the Puvirnituk hospital informed us that they could not assume this extra work load; their position was supported by the direction of the hospital. Hence, we decided to hire two field work coordinators based in Puvirnituq and Inukjuak who are now in charge of performing the work required in order to implement the present study. The study is limited to the communities of Puvirnituk and Inukjuak, and the number of participants was reduced to 150. Validation of anti-Hib measurements using plasma samples was also affected. Laboratory technicians, midwives and all medical professionals who are involved in the data collection process were met in Puvirnituk by the research coordinator (Quebec City) in order to present the objectives of the research and the research procedures early in 1999. The training of field work coordinators took place in Puvirnituq in February and in Quebec in March 1999. Data collection started in April 1999.

RESULTS

No results are available yet.

Expected Project Completion Date: Recruitment began in February 1999. Approximately, 150 mothers and infants will be enrolled over the entire study period: 10 in 1998/1999, 70 in 1999/2000 and 70 in 2000/2001. Collection of samples (6 months of age) will end in Fall of 2001. Up-to-date reports will be presented to the Northern Contaminants Program (NCP) and to the Nunavik Nutrition and Health Committee each year. The project will be completed in March 2002.

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MERCURY IN SALLUIT: TEMPORAL TREND AND INTERACTION WITH SELENIUM

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OBJECTIVES

1. To reassess mercury exposure in 150 Sallumiut who participated in the biological monitoring project of Health Canada in the 1970s, using hair and blood samples.
2. To quantify selenium levels in plasma, blood and urine samples of participants.
3. To investigate mercury/selenium interaction using oxidative stress biomarkers.

DESCRIPTION

Between 1971 and 1978, Health and Welfare Canada (Medical Services Branch) carried out mercury exposure assessments in 350 Native communities in Canada (Wheatley 1984, HWC 1991). Higher percentages of elevated blood mercury levels were found in Quebec. Salluit inhabitants in particular were found to have unexpectedly high levels: 17% of the test results were over 100 $\mu g \cdot L^{-1}$, whereas in the other Nunavik communities, only 2% of the test results were over 100 $\mu g \cdot L^{-1}$ (concentrations higher than 100 $\mu g \cdot L^{-1}$ are considered to cause health problems). Further investigation in Salluit was deemed "imperative" (Wheatley and Wheatley 1981) to find the cause of these high levels of mercury.

This investigation was undertaken in 1978 with the co-operation of Salluit's Municipal Council, Kativik Regional Government (KRG) and Makivik Corporation. Health and Welfare Canada (HWC) overviewed the blood and hair samples as well as the eating-pattern survey. Makivik provided the harvesting data and the federal Department of Fisheries and Oceans (DFO) tested for mercury levels in traditional/country food species used in Salluit. The data to be collected "were expected to provide the basis on which recommendations could be made to the community about future consumption of traditional/country food. A primary aim was to ensure that the protein food source for the people of Salluit was not curtailed unnecessarily, while at the same time trying to minimise the risk of adverse effects from the consumption of food containing methylmercury." (Wheatley and Wheatley 1981). Regardless of the expected data from the investigation, a recommendation was nevertheless made to the community in 1978 "to avoid eating seal liver until more satisfactory data were available" (ibid.).

According to Wheatley and Paradis (1995), news coverage of the problem by CBC Radio intensified concerns in the community with references to Minamata disease, and food consumption patterns were greatly disrupted in Salluit for some time because "people stopped eating their traditional diet and, as there was no available, affordable, acceptable food alternative, a crisis situation resulted" (ibid.). In 1979, a food survey questionnaire was taken to Salluit for discussion with the Community Health Committee. The food survey data analysed with the mercury and harvest data lead to the conclusion that the main source of mercury exposure was the consumption of beluga and lake trout (ibid.).

After the research was completed, Makivik Corporation as well as HWC returned to Salluit in 1980 to meet with the Salluit Health Committee and the Municipal Council. Their recommendations to the community were as follows: "[...] not to stop eating country food, but rather to eat as much as desired from the 'safe' list. However, care was recommended with beluga, large lake trout, and liver from large seals. The latter recommendation applied especially to pregnant women. Because the foetus is more sensitive to the effects of mercury than an adult [...], it was recommended that pregnant women should try to avoid beluga [meat and mattaq], large lake trout, and seal liver, or at least to eat them only in very limited quantities, if other country food is available." (Wheatley and Wheatley 1981).

In 1992, the Québec Health Survey conducted in

Nunavik reported an average mercury blood concentration of 104 nmol·L^{-1} (20 µg·L^{-1}) (Dewailly *et al.* 1994). More recently, a cord blood monitoring program was implemented in Nunavik in which mercury and selenium blood concentrations were measured at birth. Mean mercury concentrations in blood were 6.5 nmol·L^{-1} in southern newborns, 96.6 nmol·L^{-1} in Nunavik newborns, and 73.5 nmol·L^{-1} in Salluit newborns. Mean selenium blood levels were 2.4 µmol·L^{-1} in southern babies, 4.2 µmol·L^{-1} in Nunavik newborns, and 5.0 µmol·L^{-1} in Salluit newborns

Methylmercury (MeHg) is a highly toxic environmental neurotoxin that can cause irreversible damage to the central nervous system, and to which the developing fetal brain is especially sensitive (Choi 1989, Clarkson 1993, Clarkson 1997). Methylmercury toxicity resulting from developmental exposure was first identified in the mouse (Spyker *et al.* 1972) and further documented in this and other animal models including monkeys (Rice 1996a). The lowest dose of MeHg that may impair neurodevelopment in the human fetus is not known. Today, the chief concern is with the effects arising from prenatal exposure such as early sensory motor dysfunction (e.g. delayed onset of walking, and talking), delayed development and cognitive changes in children. There is also growing evidence for delayed neurotoxicity produced by MeHg (Rice 1996b). Although the underlying biochemical and molecular mechanisms that lead to impaired cell function and nerve cell degeneration are not well understood, there is abundant evidence supporting the hypothesis that a major mechanism of MeHg neurotoxicity involves an oxidative stress (Sarafian *et al.* 1991, Yee and Choi 1996). Mercurials promote increased production of reactive oxygen species (ROS) via deregulation of mitochondrial electron transport as well as through glutathione (GSH) depletion (Lund *et al.* 1993). The oxidative stress hypothesis is clearly supported by the finding that MeHg neurotoxicity can be inhibited by various antioxidants including selenium (Park *et al.* 1996) and N-acetyl-L-cysteine, a precursor of GSH (Ornaghi *et al.* 1993).

Selenium has been shown to counteract the toxicity of MeHg in many experimental systems (reviewed in Whanger 1992) including neurone cultures (Park *et al.* 1996). Of particular interest, rodent studies suggest that maternal dietary selenite supplementation may provide partial protection against some postnatal adverse effects resulting from exposure to MeHg *in utero* (Fredriksson *et al.* 1993). The mechanism of protection by selenium is poorly understood. On one hand, selenium is known to bind directly to mercury and thus participate in its sequestration. On the other hand, selenium supplementation is also known to boost the cellular antioxidant defence by stimulating the synthesis of several selenium-dependent enzymes including cytoplasmic glutathione peroxidase (GSHPx), a key enzyme in the detoxification of peroxides and prevention of oxidative DNA damage (Mirault *et al.* 1991, Mirault *et al.* 1992). As we have shown recently, one consequence of enhanced GSHPx activity can be an inhibition of transcription factor NF-kB activation by oxidative stress, which prevents activation of NF-kB-dependent gene expression (Kretz-Remy *et al.* 1996, Renard *et al.* 1997). Partial prevention of MeHg-mediated oxidative stress and consequent alterations of the developmental program by maternal selenium supplementation (and GSHPx increase) may reduce the risk of neurodevelopmental alterations and mental retardation that could be associated with maternal exposure to mercurials.

During a Northern Contaminants Program (NCP) Mercury Workshop held in Ottawa in December, 1997, a number of priority recommendations were set regarding mercury. The present research project, specifically requested by Salluit elders, aims to address some of these priorities. These pertain to both health issues (especially the effectiveness of consumption advisories, role of selenium and temporal trends of Hg exposure) and policy issues (especially the impact of delivery of Hg results, decision-making and understanding of the information). The research project will provide valuable information to both the requesting community and other stakeholders involved with contaminants research and monitoring activities in the Canadian Arctic because it is possible to compare present levels with those measured twenty years ago in the same individuals.

ACTIVITIES IN 1998/1999

In the spring and fall of 1998, consultation was undertaken with the Salluit Municipal office, the Local Health Committee members and Innulitsivik Health Centre in order to organise the field work. The following steps were undertaken:

- Recruitment of research assistants.
- Revision of the population list in order to identify participants in the 1999 survey. The original list of the 1978 survey, supplied by Medical Services Branch - Health Canada, contained 312 names. A first verification of the list excluded 82 participants, either because they had died or they were no longer residing in Salluit.
- Meetings with the Municipal Council and the Health Committee. The agenda for these meetings included: a presentation of the project; the logistical organization (lodging, working spaces, available equipment); discussion over the content of the consent form to be signed by all participants; planning of a radio phone-

in show; decision upon the dates for the exposure assessment; and discussion on ways of returning results to the Sallumiut.

- Presentation of the project to the Council of Physicians, Dentists, Pharmacists and Midwives (CPDPM) in order to have the hospital support if needed. The CPDPM has agreed, by resolution to grant approval for the research project.
- Meeting with the nursing staff of the Salluit nursing station in order to inform them about the project objectives and discuss some aspects of the logistical organization.
- Preparation of sampling protocol and laboratory analysis protocols for blood, hair and urine analysis (mercury and selenium) and for alveolar air (pentane) (in collaboration with the Québec Toxicology Centre-CHUQ).
- Training of the nurse responsible for the sampling of participants.

The following activities took place between February 1 and March 26, 1999:

- Training of the local research assistant.
- Interviews with participants and collection of all biological samples were performed. Of the 230 individuals still on the list after the first revision, 36 more were excluded either because they were deceased or were non-residents. In all, 194 individuals were invited to participate in this survey and a total of 140 (72.2%) Sallumiut agreed to participate. Furthermore, biological samples were obtained from four additional individuals who were not part of the 1978 study but who were interested in knowing their mercury body burden. The individuals accepting to participate were given appointments with the nurse working specifically on this project. Upon signature of the consent forms, they agreed to provide urine samples collected overnight, venous blood, hair and alveolar air samples. All biological samples were stored (–20°C) and sent either to the Indian and Northern Health Laboratory (Medical Services Branch, Health Canada) or to the Québec Toxicology Centre Laboratory. Blood samples and hair were used to assess short-term and long-term exposure to mercury, respectively. Selenium was measured in plasma, whole blood, hair and urine samples. Several important demographic variables as well as dietary information (to reveal sources of mercury and selenium exposure) and information recall concerning impacts of 1978 consumption advisories were collected via a questionnaire (see Dewailly et al. Reference to other study in this report).

RESULTS

Table 1 shows the distribution of the participants by sex and by age. Women represented 59% of the participants. Forty-three percent of participants were in the 18–39 years age group, 35% in the 40–59 years age group and 23% in the 60+ years age group.

Results of mercury analysis in blood samples are presented in Tables 2 and 3. A statistically significant difference was noted between men and women with regard to inorganic mercury concentration, with women showing the higher concentrations (Table 2). Mean mercury concentrations increased with age; participants aged more than 60 years had a mean total mercury concentration 3 times higher than that of individuals in the 18–39 years age group (Table 3).

Concentrations of selenium in blood, plasma and urine samples of participants are presented in Tables 4 and 5. Blood concentration tended to be higher in women than in men (Table 4). There were also age-related differences for selenium concentrations in all three biological fluids (Table 5). The largest differences were noted between the first two age groups.

Strong correlations were observed between mercury concentrations (total or inorganic) and selenium concentrations in blood (Table 6). Weaker but nevertheless statistically significant correlations were noted between mercury blood levels and plasma or urine selenium levels.

Differences in mercury exposure among Sallumiut between 1978 and 1999 were assessed by comparing the mean concentrations of mercury in hair samples, for two different age groups (Table 7). Concentrations measured during 1999 in the 18–39 years and 40–59 years age groups were respectively 2.6 and 2.1 times lower than those documented during the 1978 survey.

DISCUSSION/CONCLUSION

Results obtained to date indicate that there are large differences between age groups with regard to mercury and selenium exposure in Sallumiut. Dietary questionnaire data will be helpful to identify the factors responsible for these differences. The strong correlation noted between mercury and selenium concentrations suggests that both substances originate from common dietary sources. This may be of utmost importance in assessing the health risk associated with mercury exposure in this population. Analysis of oxidative stress biomarker data will provide information on the possible protective effect of selenium against mercury-induced toxicity in this population.

Table 1. Proportion of participants in the 1999 Salluit mercury survey by sex and age group

	18–39 years		40–59 years		60+ years		
	N	%	N	%	N	%	Total
Women	36	59	31	63.3	17	53.1	84
Men	25	41	18	36.7	15	46.9	58
Total	61	100	49	100	32	100	142

Table 2. Mercury concentration (nmol·L^{-1}) in blood of Sallumiut according to gender

Mercury	Sex	n	Geometric mean	95% confidence interval	Range	t test p value
Total	Female	84	84.4	72.1 - 98.9	7 - 348	0.06
	Male	58	64.3	50.3 - 82.0	5 - 405	
Inorganic	Female	84	14.3	12.5 - 16.5	2 - 54	0.02
	Male	58	10.8	8.9 - 13.2	2 - 52	

Table 3. Mercury concentration (nmol·L^{-1}) in blood of Sallumiut according to age groups.

Mercury	Age group	n	Geometric mean	95% confidence interval	Range	f-test p value
Total	18 - 39	61	45.3	37.8 - 54.3	5 - 130	0.0001
	40 - 59	48	93.4	75.2 -116.1	13 - 405	
	60+	32	148.5	127.1 - 173.6	55 - 348	
Inorganic	18 - 39	61	8.4	7.3 - 9.8	2 - 45	0.0001
	40 - 59	48	14.7	12.4 - 17.7	2 - 52	
	60+	32	23.6	20.4 - 27.1	11 - 54	

Table 4. Selenium concentration (mol·L^{-1}) in various biological fluids from Sallumiut according to gender

Biological fluid	Sex	n	Geometric mean	95% confidence interval	Range	t test p value
Plasma	Female	83	1.8	1.8 - 1.9	1.2 - 3.2	0.33
	Male	58	1.9	1.8 - 2.0	1.4 - 3.5	
Blood	Female	84	9.7	8.5 - 11.1	2.3 - 29.0	0.05
	Male	58	7.9	6.7 - 9.3	2.4 - 40.7	
Urine	Female	81	2.6	2.3- 2.9	0.8- 6.7	0.52
	Male	54	2.8	2.4 -3.2	0.8 - 8.8	

Table 5. Selenium concentration in various biological fluids from Sallumiut according to age groups.

Selenium conc. µmol·L^{-1}	**Age group**	**n**	**Geometric mean**	**95% confidence interval**	**Range**	**f-test p value**
Plasma	18 - 39	61	1.7	1.7 - 1.8	1.3 - 2.5	0.0001
	40 - 59	48	1.9	1.8 - 2.0	1.2 - 3.2	
	60+	31	2.1	2.0 - 2.3	1.5 - 3.5	
Blood	18 - 39	61	6.7	5.9 - 7.7	2.4 - 21.7	0.0001
	40 - 59	48	10.4	8.7 - 12.5	2.3 -40.7	
	60+	31	12.3	9.9 - 15.3	2.5 - 34.5	
Urine	18 - 39	57	2.1	1.9 - 2.4	0.84 - 5.8	0.0001
	40 - 59	45	3.0	2.6 - 3.4	0.83 - 8.8	
	60+	32	3.4	2.8 - 4.0	0.91 - 6.6	

Table 6. Pearson correlation coefficients between blood mercury concentrations and selenium concentrations in various biological fluids

Concentration nmol·L^{-1}	**Plasma selenium n=141**		**Blood selenium n=142**		**Urinary selenium n=135**	
	r	p	r	p	r	p
Blood mercury (total)	0.44	0.0001	0.75	0.0001	0.49	0.0001
Blood mercury (inorganic)	0.39	0.0001	0.71	0.0001	0.46	0.0001

Table 7. Concentrations of total mercury in hair samples (µg·g^{-1}) collected from participants in the 1978 and the 1999 surveys.

Age group	Survey	n	Geometric mean	95% confidence interval	Range	t test p value
18-39 years	1978	52	15.1	12.6 - 18.2	3.3 - 67.4	0.0001
	1999	52	5.7	4.5 - 7.2	0.5 - 19.5	
40-59 years	1978	35	22.7	19.1 - 27.1	7.5 - 50.0	0.0001
	1999	45	10.8	9.1 - 12.9	2.8 - 34.9	

During 1999/2000, the redox status will be assessed in participants. Increased selenium levels may confer enhanced antioxidant capacity, notably by increasing the synthesis of seleno-glutathione peroxidases; in contrast, exposure to mercurials is thought to generate oxidative stress (see rationale under "Description"). We shall thus measure in plasma and whole blood samples the major glutathione cycle-associated antioxidant enzyme activities responsible for peroxide detoxification. The latter include selenium-dependent GSHPx and selenium-independent glutathione peroxidase activities, glutathione reductase, total GSH/GSSG levels and total plasmatic antioxidant status as measured by capacity to quench a radical dye probe. Whole blood hemoglobin will be measured for normalization of the antioxidant activity data. The level of pentane in alveolar exhalation air will be measured as index of lipid peroxidation (oxidative stress).

Expected Project Completion Date: The project will be completed in March, 2000.

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VARIANCE REPORT PROJECTS

Project Leader: Inuit Tapirisat of Canada (ITC); Centre for Indigenous Peoples' Nutrition and Environment (CINE);

Project Team: Strata360, Department of Indian Affairs and Northern Development (DIAND), Yellowknife, NT

OBJECTIVES

1. To provide more in-depth data on the importance of traditional food within CINE's *Dietary Risk Assessment Study*, through three small research projects

DESCRIPTION

A variety of dietary assessment techniques were explored, including pile sorting exercises, ranking exercises and the gathering of temporal dietary information, in several Arctic communities. Pile sorting exercises were chosen to include 25 food items (both traditional and market). The ranking exercises were designed to address taste preferences, perceptions related to the health-promoting qualities of food for children and pregnant/lactating women, and the importance of each food for the community.

ACTIVITIES IN 1997/98

South Baffin Nutritional/ Social Economic Study

In the south Baffin community of Kimmirut, ITC had the opportunity to bring together CINE researchers and Dr. William Kemp, a geographer who worked in Kimmirut in the early 1960s, to gather nutritional information in an effort to provide temporal process of dietary change in that area. CINE also conducted some additional pile sorting and ranking exercises in which volunteers were asked two questions:

1. What are the most health-promoting food items for children or for pregnant and lactating mothers?; and
2. What are the food items most important to your community?

Pelly Bay, Bathurst Inlet, Bay Chimo and Nain, Labrador Informational Meetings

The community of Pelly Bay was originally excluded from the CINE dietary study because their inclusion was deemed to be beyond the financial means of the project. The community expressed some disappointment at being excluded from the study and continually requested contaminant information. A workshop will take place with ITC, CINE and NWT Environmental Contaminants Committee (ECC) staff and scientists to explain the issue of contaminants to one of the most traditional (in terms of consuming country food) Inuit communities. Additional information meetings will be held with the Community Council, the Hunters' and Trappers' Organization and the local school. CINE will also conduct additional pile sorting and ranking exercises at this workshop which should help to develop a broad understanding of Inuit diet information. A small workshop was held in Nain, Labrador by the Labrador Inuit Association (LIA) regional contaminant coordinator concerning questions related to these two projects outlined above.

RESULTS

During the course of the year, CINE conducted various pile sorting and ranking exercises. A total of 128 interviews (Inuvialuit: 30; Kitikmeot: 15; Kivalliq: 25; Baffin: 39; and Labrador: 17) were completed. Additional group activities originally planned for March/April 1999 have been postponed to the Fall, 1999 since logistical difficulties did not allow for early implementation.

Additional workshops in areas known to be high traditional food consumption communities provided CINE's dietary/risk survey with further information, which provides for a more rigorous analysis than simply relying on their original survey. Work scheduled in Pelly Bay, Bay Chimo, Bathurst Inlet, and Nain, Labrador in the Fall should provide CINE with additional important data. Future work in Kimmirut will take place in July 1999 by CINE, NWT ECC, ITC, and Strata360.

The study in Kimmirut will allow the comparison of the contemporary Inuit diet with detailed information collected in the same community in the late 1960s. The degree of change and consistency in the community's diet over time can then be assessed.

A STUDY WITH CYNOMOLGUS MONKEYS (*MACACA FASICULARIS*) TO DETERMINE THE POTENTIAL TOXICOLOGICAL AND REPRODUCTIVE EFFECTS OF INGESTING TECHNICAL GRADE TOXAPHENE

Project Leader: Frank Iverson, Ph. D.,Toxicology Research Division, Food Directorate, Health Protection Branch, Health Canada.

Project Team: **Toxicology Research Division:** Doug Arnold and Fred Bryce: Co-study Directors; Helen Tryphonas: immunotoxicology; Rekha Mehta: carcinogenesis and immunohistochemistry; Catherine Suzuki: biochemical toxicology; Ivan Curan: molecular toxicology; Tim Schrader: genotoxicology; Gerald Cooke: reproductive toxicology; Olga Pulido: neuropathology; Michael Barker: pathology; and Eric Lok: immunohistochemistry. **Food Research Division:** Harvey Newsome, tissue residue analysis. **Bureau of Biostatistics and Computer Applications:** Stephen Hayward, statistician.

OBJECTIVES

Long-term

1. A large monkey study was initiated in May 1996 to thoroughly assess the toxicological implications of toxaphene ingestion upon the adult monkey, including reproduction and the neonatal and post-natal development of the infant. The data from this study will assist in the assessment of toxaphene's potential risk to human health and will provide information to determine whether the tolerable daily intake (TDI) for toxaphene, as set by Health Canada, is acceptable or warrants a review.

Short-term

1. To complete the reproduction component of the study to evaluate the effects of toxaphene on non-human primate reproduction;
2. To monitor the development of any clinical effects on the infants as a result of toxaphene ingestion via breast milk;
3. To determine the depletion rate of toxaphene from the blood and adipose of treated male and female adult monkeys;
4. To evaluate the immunological effects on the infants after 22 weeks of toxaphene ingestion via breast milk; and
5. To initiate dosing of the infants with a dose corresponding to that which their dams had received.

DESCRIPTION

Toxaphene, a mixture of polychlorinated monoterpenes, was initially sold by Hercules Co., as Hercules 3956, in 1945. It was the most heavily used pesticide in the United States and many parts of the world prior to being banned (Voldner and Schroeder 1990, Saleh 1991). It was registered for use on more that 168 agriculture commodities and crops in the U.S. It was also used to control ectoparasites on cattle and sheep in addition to its use for fish eradication programs (Korte *et al.* 1979). However, it has been reported that 65-90% of all the toxaphene used in the U.S. was applied to cotton in the mid 1970s (von Rumker *et al.* 1974, Eichers *et al.* 1978, IARC 1979, Korte *et al.* 1979, Federal Register 1982). Most registered usages of toxaphene in Canada were cancelled in 1980 (Agriculture Canada 1980).

At the time toxaphene was banned, it was well known that the prevailing winds had transported toxaphene for long distances (C&EN 1982). The first documented evidence of this phenomenon was attributed to Bidleman and Olney (1975, EPA 1982). Within a few years, toxaphene residues were found consistently in samples where toxaphene was either never used or not used to any significant extent (Jansson *et al.* 1979, Zell and Ballschmiter 1980, Sundström 1981, Schmitt *et al.* 1983). Toxaphene has been found in peat bogs from the Great Lake area through northeastern Canada, even though the predominant use of toxaphene was in the southern U.S. (Rapaport and Eisenreich 1986). However, whether the toxaphene found in the various arctic samples is due to volatilization of North American soil residues or by transport from other sources is an open question (Andersson *et al.* 1988, Bidleman *et al.* 1990), although some have suggested that non-North American sources may be important contributors to the amount of toxaphene found in the Canadian Arctic (Rahn 1981, Barrie 1986, Muir *et al.* 1990).

The implications of these observations were evident in a report by Dewailly *et al.* (1993) wherein the mean concentration of organochlorines in the milk fat samples obtained from Inuit people living in Arctic Québec were 2-10 times greater than in similar samples collected in southern Québec. Subsequently, Kuhnlein *et al.* (1995) reported that 50% of the dietary intake recalls collected from an indigenous population on Baffin Island in the eastern Arctic exceeded the acceptable daily intake for toxaphene. Because of these findings, and the general lack of toxicological data regarding toxaphene that conforms to present standards for toxicological testing, a chronic toxicity and reproductive study was undertaken.

Forty adult female monkeys were randomly distributed into 4 dose groups (A,B,C,D) receiving 0.0, 0.1, 0.4, and 0.8 mg/kg body weight/day, respectively, of technical grade toxaphene. Five adult male monkeys also received the high dose of 0.8 mg/kg b.w./day and five adult males served as controls.

ACTIVITIES IN 1998/99

The breeding phase of the study in which all treated and control females were mated with non-treated males occurred between weeks 76 and 102 of dosing and was completed on May 7, 1998. Ultrasound imagery procedures were used for pregnancy diagnosis and to monitor fetal growth at days 50, 100 and 150 of gestation.

All infants were born between April 17 and September 19, 1998. Clinical examinations and somatic measurements were routinely performed throughout lactation and blood samples for toxaphene analysis were collected monthly. An adipose sample was collected at 20 weeks of age for toxaphene analysis. Blood, adipose and milk were collected from the dam at the same time as samples were taken from the infant.

Dosing of the adult males was discontinued after 99 weeks of dosing. Blood and adipose samples for toxaphene analysis were collected over the next 24 weeks to determine the depletion rate of toxaphene. All males were necropsied by October 5, 1998. Tissue samples were collected for toxaphene analysis and pathological examination. Ten adult female monkeys (2A,4C,4D) that either did not become pregnant or maintain a viable infant were chosen for a depletion component of the study after 129 weeks of dosing. As of March 31, 1999 twenty weeks of sampling had been completed.

The infants were separated from their dams at 22 weeks of age and starting at 24 weeks of age, the following immunological parameters were investigated: 1) determination of antibody titers (primary IgM and secondary IgG) to sheep red blood cell antigens; and 2) quantification of peripheral blood leukocytes and subsets using flow cytometery.

At 30 weeks of age, upon completion of the immunological evaluation, dosing of the infants was initiated at a dose level corresponding to that of their dams. Blood and adipose samples for toxaphene analysis as well as blood samples for hematology and serum biochemistry will be routinely collected until the age of 70 weeks.

RESULTS

A summary of the reproduction component of the study is shown in Table 1. Data for fetal measurements by ultrasound imagery has been collated and submitted for statistical analysis, as have somatic measurements.

Analysis of toxaphene concentrations in blood and adipose from both the dams and infants as well as milk from the dams during lactation are in progress.

Analysis of toxaphene concentrations in blood and adipose from both the adult male and female depletion components are in progress.

As of March 31, 1999, 22 of the 25 infants were being dosed, and 28 of the 30 remaining (non depletion) dams had been necropsied.

Analysis of all infant immunological samples have been completed and submitted for statistical analysis.

DISCUSSION

Generalized dry skin was the most common observed clinical effect in the adult monkeys and it appears to be dose related.

Toxaphene does not appear to have any adverse effects upon reproduction with a relatively equal number of pregnancies and infants across dose groups (Table 1).

Preliminary results indicate that the depletion half-life is less than 20 weeks in blood for both the adult male and female monkey.

Preliminary blood analysis of the infant and dam during lactation indicate that the blood levels of toxaphene are considerably higher in the infant than those found in the dam. Congeners T2 (Parlar number 26) and T12 (Parlar number 50) are major isomers found in the infant blood.

Table 1. Breeding Results

Group (dose level)	# impregnated	# live births	# viable infants	Comments
A (0.0 mg/kg)	7 of 10	6 of 7 (3m, 3f)	5 of 6 (3m, 2f)	1 stillborn (f) 1 necropsy (f) : injury
B (0.1mg/kg)	8 of 10	8 of 8 (4m, 4f)	8 of 8 (4m, 4f)	
C (0.4mg/kg)	9 of 10	6 of 9 (2m, 4f)	6 of 6 (2m, 4f)	2 C-sections 1 reabsorption
D (0.8mg/kg)	7 of 10	7 of 7 (3m, 4f)	6 of 7 (2m, 4f)	1 necropsy (m) : injury
Totals	31 of 40	27 of 31 (12m, 15f)	25 of 27 (11m. 14f)	

m, male; f, female

No major clinical effects have been observed in the infants.

Expected project completion date: March 31, 2000.

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INUVIK REGIONAL HUMAN CONTAMINANTS MONITORING PROGRAM

Project Leader: Chuck MacNeil, Baffin Regional Health Board

Project Team: Jan Houseman, Program Coordinator, Inuvik Regional Human Contaminants Monitoring Program; Bill Wrathall, Inuvik Regional Health and Social Services Board (IRHSSB); Eleanor Wein, Canadian Circumpolar Institute, University of Alberta; V. Walker, Aurora Research Institute; Jay Van Oostdam, Health Canada; Olivier Receveur, Centre for Indigenous Peoples' Nutrition and Environment (CINE); Laurie Chan, CINE

OBJECTIVES

1. To obtain regional values for the concentrations of organochlorine and metal contaminants in maternal and umbilical cord blood samples, and the concentration of mercury in hair samples from pregnant women in the IRHSSB region.
2. To assess the exposure to these contaminants through the frequency of traditional/country food intake and certain other lifestyle factors.
3. To describe any relationship between contaminant levels in blood and hair samples and frequency of consumption of traditional/country foods and select lifestyle factors.
4. To develop a model that can be used to identify the parameters that are better indicators of exposure to methylmercury, and to develop a model that can be used to relate the exposure parameters.

DESCRIPTION

A baseline assessment of contaminant exposure of women and infants is being developed for the northwestern NWT. Although different in several ways, this assessment was designed in 1997/98 based on the model used by the Yellowknife/Kitikmeot Cord Blood Monitoring Program (Rohlmann 1996). Information collected will be easily integrated with data collected in similar projects completed across northern Canada. Much of the 1998/99 fiscal year was spent collecting samples for contaminant analysis. The Inuvik Regional Human Contaminants Monitoring program is currently in the final year of its three-year duration.

Trace levels of organochlorines and heavy metals are detected in the blood of northerners and the umbilical cord blood of their babies. This study measures the types and levels of human exposure, while investigating traditional/country foods as a possible source. Contaminants are a concern for northerners, many of whom value traditional/country foods in their diet. There have been several related studies documented in Jensen *et al.* (1997).

The study area includes Inuvik and its surrounding communities. The study is coordinated from the Inuvik Hospital, the primary health care facility for the region. The Inuvik Regional Health and Social Services Board (IRHSSB) serves 13 communities in the Inuvialuit, Gwich'in and Sahtu regions, including Inuit, Dene/Métis, and non-Aboriginal residents. Women who delivered their babies with the IRHSSB from June 1998 to June 1999 were invited to participate in the study.

ACTIVITIES IN 1998/99

The focus of the 1998/1999 fiscal year was to prepare for and collect quality data, and to maintain the communication between the participants, the communities, the project team and collaborators. March 30, 1999 marked the ninth month of the 12-month sample collection period. During this time, 89 women from the region were recruited as participants. From these participants, 88 questionnaires were completed, 149 blood samples were collected (including mother and umbilical cord blood samples) and 76 hair samples were collected from the scalp. Nine other women were invited to take part, but refused.

Levels of PCBs, organochlorines, toxaphene and fatty acids were measured in maternal and umbilical cord blood by the Centre de Toxicologie de l'Université de Laval at Laval University Hospital Centre. The methylmercury testing in hair was completed by Health Canada (Indian and Northern Health Laboratory, Medical Services Branch). The hair samples were collected within weeks of the delivery. The hair analysis will signify the level of methylmercury exposure for most if not all of the pregnancy term, depending on the sample length (Health Canada 1998).

The Program Coordinator administered a food frequency questionnaire to every participant near the date of confinement, to measure the intake frequency of traditional/country foods during the past year (three months before conception and during the term of pregnancy). Lifestyle factors that influence contaminant levels are examined, such as dietary changes due to pregnancy, breastfeeding previous babies, and exposure to tobacco and chemicals. Results from the questionnaire should provide several risk management options. The information provided by the questionnaire and samples will be analysed by the Centre for Indigenous Peoples' Nutrition and Environment (CINE) and Dr. Wein. It is designed to be integrated with dietary and contaminant studies conducted by CINE on Dene/Métis (Receveur *et al.* 1996) and Inuit/Inuvialuit traditional foods. This information will be combined for a more accurate analysis of the population's contaminant exposure from traditional/country foods.

The study results will be forwarded to the Project Coordinator for reporting late in the 1999/2000 fiscal year.

CINE also proposes to use the study sample data to develop a model that can be used to identify which parameters are better indicators of exposure to methylmercury, and to develop a model that can be used to relate the exposure parameters. This model can then be used to interpret results generated from other monitoring programs in other regions. These results will be reported by CINE.

Similar maternal and cord blood monitoring programs for contaminants have been completed in other health board regions of the NWT. This study was designed to be integrated eventually into one large database of human contaminant exposure representing people across the Northwest Territories.

The following activities were also completed in the 1998/99 fiscal year:

- Newsletters, issued to a growing number of participants and organisations who hold an interest in the progress of the study, continued as an important part of the communication process.
- The final preparations were made to begin the 12-month sampling phase of the study, then recruitment and sampling began in June 1998.
- A NWT Scientific Research Licence was issued to the project leader for activities conducted in 1999.
- An article about the contaminant study and contaminants in the north was submitted to community newspapers, the 'Drum' and 'Mackenzie Valley Viewer', and printed in February 1999.
- An article titled *Inuvik Regional Human Contaminants Monitoring Program, Inuvik, NWT* was published in Environmental Health Review (Houseman 1998).
- The Project Coordinator attended many Contaminant Committee meetings, chaired by the Inuvialuit Regional Corporation (IRC) Contaminant Coordinator, to discuss the IRHSSB study. Meetings were also attended in Sahtu and Gwich'in communities to discuss the study.
- The Project Coordinator attended a Risk Assessment/Risk Management Workshop in Yellowknife, hosted by the GNWT Department of Health and Social Services in the fall of 1998.
- A poster was designed for display at the Northern Science Forum, held in February 1999 in Inuvik, sponsored by DIAND and the Aurora Research Institute. A 2' by 3' copy is displayed in the IRHSSB Board Room and a larger copy will be used for display in future NCP poster sessions and related community workshops.

DISCUSSION/CONCLUSIONS

Baseline exposure assessments have been completed in the Kitikmeot, Mackenzie, Baffin and Keewatin Regions. Due to the increased awareness of contaminants and concern for human health and traditional foods, it was of interest to coordinate a similar study in the western NWT. The Inuvik Regional study will complete the territorial baseline on contaminant exposure in northerners.

Sufficient quality information was collected during the first six months of the twelve month data collection period for analysis to begin. Once the final samples are collected in June 1999, the study's focus will turn to data analysis and results reporting. The IRHSSB will file personal results with medical health records and will then report the regional results to the participants, the NCP, and interested organisations.

Expected Project Completion Date: March 31, 2000

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TRANSPLACENTAL EXPOSURE TO PCBS AND INFANT DEVELOPMENT STUDY: PARTICIPATION RATE, RETENTION RATE AND SATISFACTION OF PARTICIPANTS

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Project Team: Christine Bouffard, Karine Poitras and Carole Vézina, Unité de recherche en santé publique, CHUQ, Pavillon CHUL; Renée Bérubé, Sonia Narang, Candace Cowling and Brenda Tuttle, Wayne State University

Special Collaboration of the Nunavik Nutrition and Health Committee: Minnie Grey, Louisa Nashak, Shirley White-Dupuis, Jean-François Proulx, Jacques Grondin, Charlie Adams, Suzanne Bruneau, Serge Déry, Jacob Partridge, Daniel Leclair.

OBJECTIVES

1. To examine the consequences of *in utero* and lactational exposure to PCBs on Inuit infants from birth to 12 months of age.

DESCRIPTION

The participation and retention rates of the ongoing study on the effects of *in utero* and lactational exposure to PCBs on Inuit infants, from birth to 12 months of age are presented, as well as results of a brief survey conducted among mothers regarding their experience and satisfaction with participating in such an elaborate longitudinal study with their infant. This survey was conducted to answer ethical concerns expressed by a few health professionals.

ACTIVITIES IN 1998/99

Data collection for this ongoing longitudinal study started in November 1995 and will end in August 2001. The continuation of data collection was the main activity carried out in 1998/1999. In addition, a brief satisfaction survey was carried out among the study participants, in collaboration with the Nunavik Nutrition and Health Committee (NNHC).

METHODS

The research protocol of the longitudinal study and laboratory methods have been described in a previous Synopsis of Research Conducted under the Northern Contaminants Program (NCP) report (Muckle *et al.* 1999).

The NNHC proposed to conduct a satisfaction survey in order to address concerns expressed by some Nunavik health professionals based in one of the three communities involved in the longitudinal study. The questionnaire was developed in collaboration with the NNHC members and was made up of six Yes/No and five multiple choice questions focussing on: 1) participants' general satisfaction with the study; 2) research procedures regarding enrollment, consent, quality of information provided, confidentiality, and respect of participants shown by research assistants; 3) perceptions of participants regarding the content of the interviews performed in the course of the longitudinal study; and 4) benefits from participation and suggestions to improve future research protocols.

Out of a total of 91 women who had participated in all phases of the longitudinal study as of March 1999, 25 women were solicited to participate in this survey. These women were randomly selected to represent the three communities involved in the longitudinal study. They were selected by designating one out of every five women on our list of participants; this list was produced in the order of enrollment in the study. Phone interviews were performed in Inuktitut by one Inuit man, who is independent of our research group, is a member of the Nunavik Nutrition and Health Committee, and who works for the Nunavik Regional Board of Health and Social Services. Twenty-one phone interviews were performed. Eight of the interviewees were from Puvirnituk, nine from Inukjuak and four from Kuujjuaraapik. Four women could not be reached by the interviewer.

RESULTS AND DISCUSSION

Participation and Retention Rates for the Ongoing Longitudinal Study

From November 1995 to the end of March 1999, 167 mothers completed the prenatal interview, 122

Table 1. Participation and Attrition Rates.

Declared pregnancies (N=230)		
Exclusion (already in study)	27	11.7%
Unable to contact (5/203)	5	2.5%
Initial participation rate (167/198)	167	84.3%
Initial refusal rate (31/198)	31	15.7%
Initial general attrition (63/230)	63	27.4%
Eligible for postnatal interview (N=156)		
Exclusion:		
Moved to another village	4	2.6%
No biological sample*	9	5.8%
Baby adopted in another village	9	5.8%
Miscarriage and perinatal mortality	8	5.1%
Unable to contact (1/126)	1	0.8%
Participation rate (122/125)	122	97.6%
Refusal rate (3/125)	3	2.4%
General attrition (34/156)	34	21.8%
Eligible for 6.5 month assessment (N=115)		
Exclusion : Medical condition	1	0.9%
Moved to another village	2	1.7%
Died	1	0.9%
Unable to contact (2/111)	2	1.8%
Participation rate (1/109)	108	99.1%
Refusal rate (1/109)	1	0.9%
General attrition (7/115)	7	6.1%
Eligible for 11 month assessment (N=93)		
Exclusion : MOved to another village (1/93)	1	1.1%
Unable to contact (0/92)	0	0%
Participation rate (92/92)	92	100%
Refusal rate (0/92)	0	0%
General attrition (1/93)	1	1.1%

* No biological sample had been taken at birth, therefore the child was excluded

completed the postnatal interview; 108 infants were assessed at 6.5 months and 92 were assessed at 11 months of age (Table 1).

The initial participation rate was 84% (167/198) and comparable to the 80% we had projected. Only three mothers out of the 125 eligible (2%) refused to continue in the study after completing the prenatal interview. This refusal rate was markedly low, as were the refusal rates of 1% and 0% at 6.5 and 11 months, respectively. One source of subject loss which we had not anticipated was due to mothers already having enrolled in the study with a previous child (11.7% of all declared pregnancies). Attrition due to perinatal mortality or miscarriage was markedly lower than the 16.1% projected. However, postnatal attrition has been somewhat higher than projected due to difficulties associated with reaching mothers without telephones and mothers moving to other villages who, given the high cost of travel, could not be assessed.

Preliminary exposure data were presented in a previous NCP Synopsis of Research report (Muckle *et al.* 1999), and effects analysis will not be performed before the sample size reaches statistical power of 0.80.

Results of the Satisfaction Survey

In order to respect confidentiality, the interviewer did not inform the research team of the identities of the participants, so it is impossible to extract from the longitudinal study database the socio-demographic and socio-economic characteristics of this sub-sample.

Almost all the interviewees (95%) responded "very much" or "pretty much" when asked how they liked participating in the longitudinal study (Table 2). Ninety percent of the survey participants felt that no improvements are required to make this project better, and 90% said they would agree to participate in this study again. They considered themselves "very well informed" (76%) or "somewhat well informed" (14%) that their participation was on a voluntary basis, and that they could have refused to participate or withdrawn from the study at any time. They believed that the information provided to the research team members remained confidential (95%). Almost all interviewees felt that the research assistant was always or most of the time (95%) respectful towards them and their babies.

More than two-thirds (71%) of the respondents thought that they did not need more information about the study

Table 2. Detailed Results of the Satisfaction Survey

1. General satisfaction with participating in the study
   Very much and pretty much: 95%
   Not very much: 5%
   Not at all and no opinion: 0%

2. Information provided on voluntary basis of participation; possibility to refuse to participate or to withdraw from the study:
   Very and somewhat informed: 95%
   Not too informed: 5%
   Not at all informed and do not remember: 0%

3-4. Respect toward mother and child:
   Always and most of the time: 95%
   Sometimes: 5%
   Rarely or never: 0%

5. Discomfort with questions asked
   No: 86%
   Yes: 14% (3/21)
   Comments for 'Yes' answers:
   1/3 too many questions about country food;
   2/3 didn't give precision

6. Need more information about the study
   No: 71%
   Yes: 29% (6/21)
   Comments for 'Yes' answers:
   2/6 needed more explanations about PCBs and environmental pollutants in general;
   4/6 did not give any reason

7. Confident of confidentiality
   No: 5% (1/21)
   Yes: 95%
   Comments for 'No' answer:
   1/1 did not understand the question

8. Satisfaction with the follow-up received throughout the study:
   Very or somewhat satisfied: 95%
   Not too or not at all satisfied: 0%
   No opinion : 5%

9. Get benefits from participation
   No: 29%
   Yes: 71% (15/21)
   Comments for 'Yes' answers:
   10/15 it is good for themselves and their child because they now have a better comprehension of their infants development, or are more aware of it, and have learned what they can do to improve it; 2/15 appreciated the money and gifts given at each interview; 1/15 thought the results will be useful to answer community concerns; 1/15 reported that the blood sample taken at 6 months had been an opportunity for the nurse to diagnose her baby's health problem; 1/15 did not give any reason

10. Improvements to do
   No: 90%
   Yes: 5% (1/21)
   Don't know: 5%
   Comments for 'Yes' answer:
   1/1 too many questions on country food

11. Would participate in this study again
   No: 10% (2/21)
   Yes: 90%
   Comments for 'no' answers:
   1/2 does not want other children;
   1/2 did not give any reason

than what had already been provided to them. All respondents (100%) were "very satisfied" or "somewhat satisfied" with the follow-up received from the study group throughout their participation. Even though some of the questions on the prenatal and postnatal interviews were very personal and focussed on issues like alcohol consumption and drug use during pregnancy, only three interviewees (14%) reported that there were questions that they would have preferred not being asked about and would have taken out of the interviews. Two of these three respondents did not specify which questions and one felt that there were too many questions about their traditional/country food consumption.

A large proportion of respondents (71%) felt they had gained benefits from their participation in the longitudinal study. Fourteen out of 15 respondents specified the benefits: 10 felt they now have a better understanding of their infant's development and have learned how to improve it; two appreciated the financial compensation provided to them for their participation and the toys given to their infant; one reported that the study results will be useful to answer community concerns; one informed us that the medical visit (when the baby is 6 months old) had been an opportunity for the nurse to diagnose her baby's health problem.

CONCLUSIONS

So far, the participation rate in the present study has been high and very few women have withdrawn their collaboration during the course of the study. The high participation rate, the very low refusal rate after enrolment, and the satisfaction survey clearly indicate that the mothers enjoy participating in this research. They are very comfortable with the research procedures, including the content of the interviews, and they feel that they have received various benefits from their participation. This survey also indicates that the rules of ethics regarding informed consent, confidentiality, and respect for study participants, are adhered to in the course of this longitudinal study.

Expected Project Completion Date: December 2001.

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ANNEX 1
SATISFACTION SURVEY QUESTIONNAIRE

INTRODUCTION

Hello, my name is __________, and I work for the Nunavik Regional Board of Health and Social Services. I have been asked by th Nunavik Nutrition and Health Committee to get in touch with you to see if you are satisfied or not abut the Infant Development Study in which you and your child had recently participated. I would also take this opportunity to discuss with you any improvement you would feel necessary.

Questions:

1) How old is your child who's taking part in the study?
__________months old

2) Could you tell me if you liked participating in this study?
Yes, very much
Yes, pretty much
No, not very much
No, not at all
No opinion

3) Were you well informed the first time you met the evaluator that your participation was on a voluntary basis and that you might have refused to participate or to withdraw from the study at any time?
Very informed
Somewhat informed
Not too informed
Not at all informed
Do not remember

4) Were the evaluators respectful towards you?
Always
Most of the time
Sometimes
Rarely
Never

5) Were the evaluators respectful towards your child?
Always
Most of the time
Sometimes
Rarely
Never

6) I wonder if there are some interview questions you would have preferred not being asked about and taken out?
Yes
No
If yes, which topics? ______________________________
____

7) Do you think you need more infromation about the study than what has already been provided to you?
Yes
No
If yes, which? ______________________________
____

8) Do you feel that all the information you gave to the researcher remained confidential?
Yes
No
If no, why? ______________________________
____

9) Are you satisfied of the follow-up you received throughout your particpation in the study?
Very satisfied
Somewhat satisfied
Not too satisfied
Not at all satisfied
No opinion

10) Can you identify any benefits from your participation in the study for now or in the future, for you, your child or other Nunavimmiut?
Yes
No
If yes, which ones? ______________________________
____

11) I wonder if there are any improvements that would make this project any better?
____
____

12) Finally, if you were to start all over, would you participate in this study again?
Yes
No
If not, why? ______________________________
____

ASSESSMENT OF RADIATION DOSES TO NORTHERN RESIDENTS FROM CONSUMPTION OF CARIBOU MEAT

Project Leaders: Bliss L. Tracy and Anar S. Baweja, Radiation Protection Bureau, Health Canada, Ottawa, ON

Project Team: Patricia Thomas, Toxicology Centre, University of Saskatchewan; Northern Health Services, Saskatchewan Health Department; Environment Canada (Prairie Region)

OBJECTIVES

Short-term

1. To measure the uptake and retention of polonium-210 (^{210}Po) by the human body and to develop simple screening procedures that can be applied on a community-wide basis to measure polonium intakes. This will allow a more accurate assessment of radiation doses to northern communities.

Long-term

1. To address concerns of northern residents about the safety of country/traditional foods and to establish reliable guidelines and recommendations.

DESCRIPTION

Recent work carried out under contract to Health Canada (Beak 1995, Beak 1996) showed that some northern populations may be receiving substantial radiation doses: 5-15 mSv per year compared to a normal background of 2-3 mSv per year. About 70% of the enhanced dose resulted from one radionuclide, polonium-210 (^{210}Po), and one pathway: the lichen ø caribou ø human food chain.

A major uncertainty in this assessment lay in the amount of ingested polonium actually absorbed by the human gastro-intestinal (GI) tract. There is also uncertainty about how long ^{210}Po is retained by the various body organs. The current study was undertaken to resolve these uncertainties. An accurate knowledge of these parameters is essential in assessing the impact of human activities, such as uranium mining, on northern lifestyles.

ACTIVITIES IN 1998/99

During 1998/99, ^{210}Po uptake studies were carried out on a further eight volunteers in the Saskatoon area, to complement the results from the first six volunteers in 1997/98. Dr. Patricia Thomas, Toxicology Centre, University of Saskatchewan, again coordinated the study. In January 1999, each volunteer consumed about 2 kg of freshly killed caribou meat. Urine and fecal samples were collected over a period of two months. Analyses for ^{210}Po in meat, urine, and feces were carried out by the Saskatchewan Research Council in Saskatoon. The Environmental Measurements Laboratory in New York performed Quality Assurance on the analyses. The University Hospital in Saskatoon assisted with sample collections and creatinine measurements in urine as a verification of completeness of the 24-hour urine collections.

RESULTS

The results for the gastro-intestinal uptake factor, f_1, for the 14 volunteers are summarized in Table 1.

DISCUSSION/CONCLUSIONS

It can now be concluded that, for human populations consuming caribou meat, the GI uptake factor for ^{210}Po is well known. The final value obtained, 0.61 ± 0.04, is only slightly greater than the International Commission on Radiological Protection (ICRP) recommended value of 0.50. This validates earlier dose assessments carried out by Health Canada (Beak 1995, Beak 1996) and the Centre for Indigenous Peoples' Nutrition and Environment (CINE) (Berti *et al.* 1998), which indicated elevated radiation doses from ^{210}Po for northern populations dependent on caribou.

The doses are not excessively high; they are 2-3 times normal background at most. However, the alpha radiation from polonium is known to be more radiotoxic than an equivalent amount of beta or gamma radiation. A further research project, funded under the Toxic Substances Research Initiative (TSRI), is underway to directly measure the biological effects of polonium alpha radiation on human and caribou tissues.

Table 1. Gastro-intestinal uptake factor, f_1, for study volunteers.

Volunteer #	Sex	Age (y)	Intake(Bq)	Excretion (Bq)	f1 = (I-E)/I
1	M	23	23.1	6.0	0.75 +/-0.06
2	M	34	23.1	13.5	0.41 +/- 0.12
3	M	33	23.1	11.9	0.49 +/- 0.10
4	M	53	23.1	7.2	0.69 +/- 0.06
5	F	24	20.0	12.6	0.35 +/- 0.11
6	F	35	20.0	9.8	0.49 +/- 0.11
7	F	34	23.9	8.7	0.63 +/- 0.03
8	F	34	23.9	10.0	0.58 +/- 0.04
9	F	48	23.9	5.6	0.77 +/- 0.02
10	F	50	23.9	4.9	0.80 +/- 0.02
11	F	35	23.9	8.4	0.65 +/- 0.03
12	M	27	23.9	no sample	no sample
13	M	30	24.6	10.3	0.58 +/- 0.04
14	M	53	24.6	4.9	0.80 +/- 0.02
Mean		36.6	23.2	8.8	0.61
Std dev		10.2	1.5	2.9	0.15
Std err mean		2.7	0.4	0.8	0.04

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Education, Communications and Community-Based Strategies

COUNTRY FOOD, NUTRITION AND HEALTH: DEVELOPING EFFECTIVE COMMUNICATION STRATEGIES IN LABRADOR

Project Team: Frank Andersen, Joanna Lampe and Frances Murphy, Labrador Inuit Association; Chris M. Furgal, CHUL Research Centre; Lorraine Craig, Consultant

OBJECTIVES

Year 1

1. To develop regionally specific characteristics for "effective" environment and health communications utilizing lessons learned from practice and theory in environmental health risk communications in the North and elsewhere, as well as knowledge gained from experienced Labrador communicators.

Year 2

1. To develop messages and test a number of commonly utilized communication pathways utilizing the guiding principles for regionally "effective" communications developed in Year 1.
2. To make general recommendations for components of environmental health communications in Labrador.

DESCRIPTION

Research has shown that traditional/country food is good for people nutritionally, culturally, and economically. The challenge for communicators is to develop messages that balance the benefits and risks associated with traditional/country foods. Communicating contaminant-related issues between researchers, public officials and local residents created problems in the past. It resulted in negative effects such as misperception of risks and some changes in traditional cultural practices. Usher *et al.* (1995) and Furgal *et al.* (1995) have documented the need to develop and evaluate culturally appropriate communication strategies.

Despite the many efforts made by various researchers to deliver contaminants information that is accurate and easily understandable, no work has been done to evaluate strategies utilized in past and current communications regarding health and the environment. Also, little has been done to develop regional definitions and guidelines for "effective" communications on issues such as traditional/country foods and environmental contaminants.

The purpose of this project was to use lessons learned from practice and research in environmental health risk communications outside Labrador, as well as knowledge gained from experienced communicators in Labrador, to develop regionally specific characteristics for "effective" environment and health communications.

ACTIVITIES IN 1998/99

A review of all pertinent literature relating to risk communication for environment and health issues was conducted. This review included sources on research and practice from southern environments as well as work that has been conducted in the North. A discussion paper was developed, synthesizing recommendations for risk communications activities aimed at the basic components of communication outlined by Covello *et al.* (1986): source, channel, message and receiver. Recommendations gleaned from the literature were considered in light of characteristics of the communications environment of the Labrador north coast.

As part of this project, and another initiative undertaken by the Labrador Inuit Association (LIA) Research Department, all available research communications materials relating to environmental health issues in the region were collected from the offices of the Research Department and LIA Head Offices in Nain, Labrador, categorized and inventoried. This inventory was conducted to identify and review all previous communications materials in the region on environmental health issues, including contaminants in traditional/country food, as well as to begin the development of a regional research library for the LIA Research Department.

Semi-structured key-informant interviews (Patton 1980) were conducted with 33 individuals from identified organizations and groups having communications responsibilities relating to health and environment issues in the region. Individuals were grouped into categories based on their employment position (people employed in the same position, but perhaps in a different community, were grouped together: e.g. fieldworkers, town council workers, public health staff etc.). Topics discussed focussed on issues related to communications activities, methods utilized, challenges encountered, and perspectives on "effective" communications in the region.

RESULTS AND DISCUSSION

The need to communicate effectively with communities on health and environmental issues has become increasingly important in regions of the Canadian North. Health professionals, Inuit organizations, hunters, elders and other members of Inuit communities are faced with the task of conveying information to reduce risks and promote health, while at the same time preserving the many benefits of traditional lifestyles. As scientific information on the nature and extent of potential environmental health risks advances, individuals and communities are seeking timely, culturally relevant, balanced communication of research findings.

Much has been reported in the literature to guide the development of effective strategies and messages for risk communication in the South (Covello *et al.* 1989, NRC 1989). While many aspects of communication are well developed through the use of radio, workshops, videos, and fact sheets, research on risk communication in the North is in its infancy. Lessons have been learned from case study analyses of communication of health advisories related to chemical contaminants in traditional/country food in Aboriginal communities (Usher *et al.* 1995, Peters and Legare 1999, Furgal 1999). Research has been carried out to better understand from the perspectives of northern communicators and local residents, the unique challenges of benefit and risk communication in the North, communication and information needs on environmental risks, and perceptions of risks and benefits related to environmental contaminants (Usher *et al.* 1995, O'Neil *et al.* 1997, Poirier and Brooke 1999, Furgal 1999). Together, this information provides a basis for beginning to identify how to communicate effectively with Northern communities on environment and health issues.

A total of 197 communications items relating to environmental health issues in the region were identified and summarized in the inventory conducted in Nain. This included: research projects (31); Annual General Meeting reports (20); posters, pamphlets and booklets (13); videos (7); press releases (7); final reports, which included the submission to the Voisey's Bay EIS Panel, proposals, handbooks for community projects and research, journal articles and newsletters (5); and other related communications items (114).

Thirty-three individuals were identified and interviewed as key-informants for this study. They were categorized as either: Town Council employees, LIA executives, LIA other, Labrador Inuit Health Commission (LIHC) team leaders, LIA fieldworkers, LIHC community health representatives, public health staff, or other. Members of the "other" category were employees of regional and local TV and radio stations, or were local communications experts working with one of the organizations present in the community.

All respondents were actively employed in an organization in a Labrador community and involved in some form of communications activities as part of their responsibilities. A large number of individuals are actively communicating on a variety of health and environment issues in Labrador. Most (29/33) are communicating directly at the community or local level, with few disseminating information regionally. The majority of communicators reported utilizing television and radio for these activities (TV/radio: 26/33; print: 22/33; other: 22/33).

Respondents indicated a number of challenges in their communications. These included: not knowing if audiences received messages; keeping up with a large number of issues at the same time; a general lack of audience interest; information overload among audiences; a lack of knowledge of effective media for communicating; sensitivity of certain issues; and challenges related to translation of technical information into plain language English and Inuktitut. Communicators indicated a number of ways to address these challenges, including changes related to the communicator delivering the message, the media used to deliver this information, and the actual content and development of the message delivered.

According to respondents, good communicators are:

- clear, concise, confident speakers
- honest
- good listeners
- consistently in practice and recognized
- approachable
- knowledgeable of the issues
- trustworthy
- able to accept criticism
- easygoing
- personal in their approach
- understanding of culture

According to respondents, good messages are:

- direct
- simple and understandable
- not condescending

- put in a personal context for coastal residents
- accurate
- translated accurately into Inuktitut
- include some form of feedback and evaluation
- delivered early
- considerate of the immediate environment in which they are delivered (e.g. some meetings are very intimidating for residents and this inhibits ability to ask questions and increase comprehension)

According to respondents, good channels and media include:

- a mixture of variety of forms of media (verbal, written and visual) with the same issue
- visual media in strategic places in town
- local radio
- newsletters
- posters that display information visually (illustrative)
- cable television roll-up
- distribution of pamphlets and newsletters
- use of radio announcements and phone-in radio shows
- workshops
- any opportunity for face-to-face contact in the delivery to enable feedback
- those with a planned and evaluated approach
- question and answer format of information presentation
- should include elders as resource people in delivery of messages

One respondent indicated utilizing some form of evaluation of communications activities, however, none of the identified communications material collected in the inventory included any evaluations during or following its' release. Most respondents indicated gaining some knowledge of the success of their communications efforts through informal channels (e.g. informal feedback, face-to-face comments, word of mouth in community).

Respondents indicated a number of changes in the north coast communities in the past that have made communications easier or more difficult. They included changes in peoples' listening activities ("people don't listen to radio as much anymore"), the loss of basic one-on-one communication skills with the advancement of technology, and the perspective that some technology (e.g. computers) makes information gathering and message development and dissemination more complicated. This perception stems from a lack of computer training or knowledge of the potential uses of computers in communications activities, and the resulting intimidation among some individuals. Other changes identified as making communications more difficult included the need to always communicate in both languages, the need to compete for people's attention with activities such as bingo in the community, and the growing size of communities, which makes door-to-door and face-to-face communications more difficult. Some respondents stated that medium-related changes made communications easier. Specifically, they referred to: improvements in the speed of message delivery because of equipment such as fax and email; the ease of message delivery with a community television channel which is viewed by a large number of residents; the increased availability and access to such media as television; the presence of local radio stations in each community; and an increased ability to make more eye-catching visual presentations of information with the use of computers.

Respondents indicated that communications have changed in the recent past (i.e. the last two years). Some (14/33) indicated that changes in the way they communicate related to their use of new and different media. For examples, a variety of different forms of media are used in their communications, including newly available technology (e.g. email), however, they have also realized that some past methods of communication (e.g. town meetings) are not as popular anymore and thus are not emphasized as much in current communications activities.

CONCLUSIONS

The following are recommendations based on the literature review and recommendations made from theory and practice, as well as those made by respondents interviewed. They address and are organized around the basic components of communications outlined in the classic model adapted from Shannon and Weaver (1949).

Communications Scoping

- Partnerships must be formed with health and environment authorities and community groups to collaboratively develop communications strategies.
- Goals and objectives of the communication program must be identified.
- Communications priorities, objectives and strategies that reflect community concerns and lessons learned from past communications, must be determined.

Source

- Messages must be conveyed by sources which are trusted and respected by the target audience.

Message

- Messages must be built upon local knowledge and personal experiences, local perceptions of risks, health and illness and community information needs.
- Messages must be directed towards the literacy level and language preferences of specific target audiences in the community.
- Messages must be field tested to ensure the intended meaning is conveyed.
- Messages must be simple and convey balanced information to assist in decision making, including information on costs, benefits and risks.
- Messages must be conveyed early and frequently.
- Messages must be repeated in different ways, by changing examples or the context in which the information is relevant.

Channel and Medium

- Communications must use and build upon existing local systems or channels of communication and information delivery.
- Community preferences and interests indicated through local research must be considered in the selection of communications channels.
- Two-way communications channels must be used whenever possible.

Audience (Receiver)

- An understanding of risk perception, views on health and illness, existing benefit-risk management practices, information needs, issues and concerns of the target audience must be used to form the basis of information used in the construction of policy, programs and preventative messages.

Evaluations

- Communications must build in opportunities to receive audience feedback. This can include simple methods such as the use of evaluation forms, integration of formal and informal verbal feedback opportunities at meetings and after announcements are released, and the use of call-in radio programs on specific topics to obtain feedback on written materials, workshops, meetings, etc.

Communications Support

- Organizations responsible for dissemination of this information must support communications activities through training and open, active, internal communication networks. A regional and inter-community communications network should be developed for information exchange and communications capacity development.

Expected Project Completion Date: Year 1 of the project activities are completed and Year 2 of this continued project is expected to be completed in June 2000.

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LABRADORIMIUT PERSPECTIVES ON ENVIRONMENTAL HEALTH

Project Team: Frank Andersen, Joanna Lampe and Frances Murphy, Labrador Inuit Association (LIA); Chris M. Furgal, CHUL Research Centre, Beauport, QC

OBJECTIVES

1. To organize a recently compiled qualitative database on Labrador coastal residents' perspectives and concerns regarding environmental health and traditional foods.
2. To conduct further analysis on this database and develop detailed information to communicate to the Labrador Inuit, and to help focus future research efforts relating to environmental health and traditional foods in Labrador.

DESCRIPTION

The way of life of Labrador Inuit has always been defined by their relationship with the environment. The harvesting of resources from the land and waters has provided not only the primary source of food and income in the past, but also the foundation of the social and cultural way of life in this region. Their relationship to the land and resources, strengthened through activities of hunting, fishing and trapping, continues to be an important source of psychological well-being and health of individuals in the communities. However, this relationship with the land and its resources is changing (LIHC 1996). Labrador, similar to many other regions in the North, is undergoing great economic, political, socio-cultural and environmental changes as a result of influences and pressures both from within and external to the region. The loss of the ground fishery and fur markets has had significant effects on communities. In turn, a lack of cash income required for investment in equipment and supplies has made it difficult for many to continue harvesting wildlife and gain access to their traditional foods. Land claims and self-government settlements, and mineral exploration and development projects are just two examples of the significant forces affecting residents' lives in this region. People express concern about the loss of culture and language, and access to, and health of wildlife on a daily basis (Williamson 1997, LIHC 1996).

Perceived and real risks of contaminants in Labrador country/traditional foods pose significant threats to the way of life for residents in this region. This is a region once thought to be clean, healthy and untouched. Over the past fifteen years, evidence to the contrary has been recorded. Elders have noticed and discussed changes in the environment similar to those reported elsewhere in the Canadian North (Williamson 1997, LIHC 1996, Williamson 1996). Reports of more sick animals, fewer numbers of some species, and significant changes in wildlife behaviour and health have been reported (Williamson 1997, LIHC 1996, Williamson 1996). In 1987, a provincial health advisory informed the region that the George River caribou herd was contaminated with cadmium and that livers and kidneys of these animals were no longer safe to eat. In 1989, PCBs were discovered on a radar site in a region of Northern Labrador traditionally hunted and fished by Inuit. Through a number of cooperative efforts, the LIA is still in the process of determining the extent of, and risks imposed by these and other sources of contamination in the region. At the centre of these issues is the concern for the protection and promotion of community and individual health in a region that is undergoing a period of rapid change.

The Eco-Research Project and the Environmental Health Study

From 1995 to 1998, the LIA was involved in the Tri-Council Eco-Research program; a multi- disciplinary research program investigating the social, economic, environmental and public health risks related to environmental contaminants in traditional foods. Originating through this program, a local research office was established to conduct projects and act as a liaison between communities and outside researchers. This office has proven to be a significant contribution to the region's research and decision making capacity. As part of this program, the importance of being aware of what Labrador Inuit already know, understand, and are concerned about regarding environmental health and contaminants was realized. To collect information on these topics, the LIA cooperatively directed, designed and conducted the Environmental Health Study (EHS) (LIA 1997). The study was designed to collect residents' perceptions, concerns and questions regarding the environment, traditional foods, and land-based activities. Specifically, the objectives of the project were to compile information on:

1. People's concerns about local industrial development (e.g. mines, etc.) and the effects that this development might have;
2. Any changes in land use and traditional food consumption as a result of industrial activities;

3. Local knowledge about natural toxins in traditional foods;
4. Concerns and knowledge about human sources of contaminants in wildlife;
5. Concerns about dumpsites, sewage and water quality in communities (LIA 1997).

Questions to be asked and target groups to be interviewed were identified through a workshop with coastal residents and health and environment representatives. A total of 222 individuals from the 5 coastal communities participated in personal interviews during the spring and summer of 1995. Individuals were categorized into 5 sub-groups within the population and randomly selected from those groups to fill predetermined sampling quotas (Table 1).

ACTIVITIES IN 1998/99

The original interview files from the EHS were located, organized and formatted for use with QSR NUD*IST 4.0 qualitative software (Qualitative Solutions and Research Pty Ltd. 1997). As interview selection was conducted on a quota basis (non-probabilistic technique), quantitative statistical analyses were not possible, however, NUD*IST allows a variety of qualitative content analysis exercises and categorical comparison functions that were impossible, or otherwise difficult, with previous versions, or done manually with large amounts of textual data. Through discussion between research team members and local health and environment representatives, areas of interest were identified within the original data base to focus further analysis. Additionally, throughout this project local researchers were trained on QSR*NUDIST 4.0. This analysis is currently ongoing as a variety of further inquiries of interest to the researchers and local population develop as results are derived from the database. Relationships within and between categories used to group individuals are being further investigated.

RESULTS AND DISCUSSION

The EHS surveyed 222 individuals from the five coastal communities (Table 1). Interviews were conducted with individuals from the following pre-determined groups: Elders, Hunters, Women of Child Bearing Age, Youth, Health Workers, Environmentalists (individuals that have been outspoken on environmental issues in the community), and a "Random" selection of individuals from the adult population. Interviews discussed a variety of issues related to land use, traditional foods, community pollution, and environmental health perspectives, and concerns. The analysis of the interviews presented here focusses on the information gathered relating to public perceptions and concerns regarding environment and health issues.

Environmental Change

Respondents indicated knowledge of changes in the environment for which they expressed concern (Table 2). Respondents in all communities showed concern for changes in animals in their region including declining numbers and health of some species, abnormalities in organs of some animals and behaviour of others. Labradorimiut reported observations of a warming climate in their region and concern for the impact these changes have on land-based activities such as traveling, hunting and fishing. Less annual snow cover, decreasing water levels in lakes and streams, and pollution in waterways were reported. Postville residents expressed particular concern over the safety of their drinking water source because of past mining activities in the region. Changes were also reported in vegetation of the region, and the perception that some of these changes were linked to pollution was expressed. Seventy-eight percent of respondents indicated that they believed they would know if changes were occurring in the environment through personal observations, by talking to Elders, receiving knowledge from hunters, or information from LIA, wildlife officers, or the Town Council. The remaining 23% of individuals did not know how people would notice or hear of environmental change.

The Environment, Country Food and Public Health

Some forms of environmental change are argued as reasons for changes in traditional/country food consumption in the region. Although the majority of individuals (56%; N=190) report no changes in their diet, the remaining minority (44%) attribute changes in their diet to such things as resource depletion, decline in animal health (some reported to be related to contaminants), and a loss of interest in country food sources. Currently, the majority of respondents report consuming traditional foods 3-4 times a week, or daily (Figure 1). The most common reasons given for preference of country foods over store bought foods include the belief that country foods are more nutritious, are fresher and have fewer preservatives and additives, that they are the main source of food for individuals, or are simply more satisfying (Figure 2). The majority of respondents (76%; N=210) reported that they were not concerned about their family's diet, and that they thought they ate well. The remaining respondents (24%) reported concern for the diet of their family because of poor diet choices that were made, a belief that they consumed too much store-bought foods and too little country food, and the concern that the children preferred store food to country food items. Despite these concerns, the majority of individuals interviewed reported a very positive perception of their health. The majority of respondents (55%) reported "good" general health, while

Table 1. Listing of sample groups within communities and numbers interviewed for the EHS (LIA 1997). Target rates were set at 10% (Random category), 20-30% (Hunters, Youth, Women of Child Bearing Age) and 100% (Health Workers, Environmentalists, Elders) as determined in a pre-survey workshop held in Nain, Labrador.

Community	Sample Group	Total Population	Target Population	Interviews
Postville	Elders	11	11	5
	Hunters	55	17	11
	Youth	32	6	3
	Women of Child Bearing Age	26	5	3
	Health Workers	2	2	2
	Environmentalists	3	3	0
	Random	130	13	7
Rigolet	Elders	18	18	9
	Hunters	40	12	7
	Youth	35	7	5
	Women of Child Bearing Age	40	8	2
	Health Workers	2	2	0
	Environmentalists	4	4	3
	Random	18	17	3
Makkovik	Elders	24	24	13
	Hunters	76	23	7
	Youth	33	7	5
	Women of Child Bearing Age	58	12	0
	Health Workers	4	4	0
	Environmentalists	4	4	1
	Random	194	19	1
Hopedale	Elders	17	17	9
	Hunters	95	29	6
	Youth	32	6	4
	Women of Child Bearing Age	68	13	8
	Health Workers	3	3	1
	Environmentalists	3	3	1
	Random	282	28	3
Nain	Elders	29	29	16
	Hunters	129	39	24
	Youth	149	30	12
	Women of Child Bearing Age	146	29	14
	Health Workers	12	12	6
	Environmentalists	10	10	10
	Random	623	62	29

Table 2. Recognized indications of environmental change for which respondents reported concern in Labrador communities (LIA 1997).

Environmental Component	Specific Concerns
Animals	• declining numbers of fish, partridges, seals, rabbits, minks, muskrats, geese and ducks • size of char noticeably decreasing • abnormalities in caribou livers • poor caribou health, and changes in behaviour • impact of low-level air traffic on caribou herd
Climate	• climate getting warmer • warmer winters, later freeze-up, earlier break-up of ice • more annual rainfall • concern expressed over climate as it has affect on what land-based activities can be done and when
Snow, Lakes, Streams	• less snow, dirtier snow, with black sooty deposits • concern that lakes, streams and marshes have dropping water levels, are permanently drying up and are polluted • pollution and litter in waterways from past mining projects • concern expressed among Postville respondents for safety of drinking water source because of past mining activities in area
Vegetation	• tree leaves fading, moss developing abnormal colour (thought to be linked to pollution) • amount of berries has decreased • concern for trees as more people appear to be relying on wood for heat

12% reported "excellent" health, 30% reported "fair" health, and only 3% reported "poor" health.

Community Health Concerns

When asked what the most important health concern in the communities was, respondents expressed concern for the number of reported cases of cancer, the number of alcohol-related incidents and illnesses, the number of cases of the flu, and the frequency and numbers of common colds in the communities (Figure 3). Priority of concern, as indicated by frequency of responses, differed between communities. A proportionally larger number of individuals reported greatest concern for the number of cases of cancer in Makkovik and Postville than other communities. This can possibly be attributed to the community's past experience with the BRINEX mining exploration site in that region. Proportionally fewer individuals reported concern for alcohol-related incidents and illnesses in Postville and Rigolet. A proportionately large number of individuals in Hopedale and Rigolet expressed the belief that the number of cases of common colds was the most important health concern, while Nain residents' greatest health concerns were distributed among the four major concerns in the region (Figure 3).

Community Environmental Concerns and Perceptions of Risk

Respondents indicated that the most important community environmental concerns included problems related to garbage in the community, the community sewage system, the town dump, or other concerns including air pollution, environmental impacts of mining and helicopter traffic (Figure 4). A proportionately large number of individuals indicated "garbage" as being the most important environmental problem in each community, with the exception of Postville. Concerns related to the sewage system were reported as the next most important environmental problem in Nain, Hopedale, and Rigolet (Figure 4).

The majority of respondents (52%; N=201) expressed a belief that environmental problems affect public health, while 43% thought that this was not the case, and 9 individuals (4%) were uncertain of the relationship between environmental problems and public health.

When asked to rank the level of personal hazard associated with a number of activities, a proportionately large number of individuals reported a perception that "drinking alcohol while pregnant", "cigarette smoking", "drinking alcohol and then driving a ski-doo", and "eating mussels in August" were very hazardous to personal

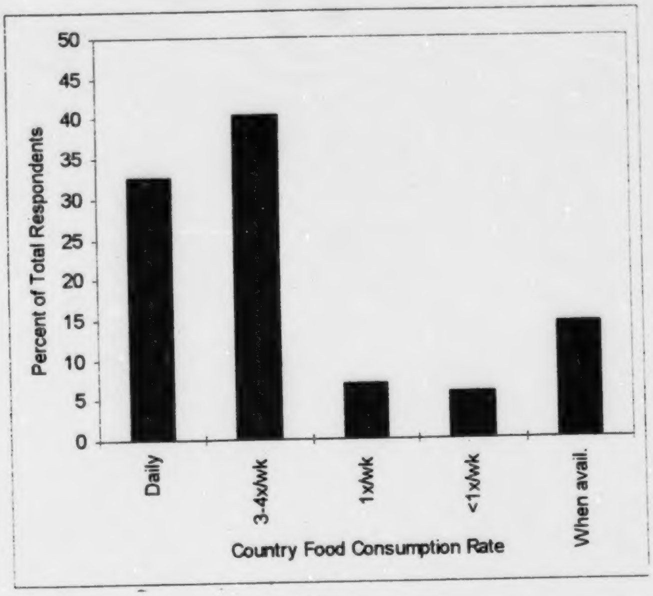

Figure 1. Country food consumption rate as reported by EHS respondents in Labrador communities (N-104; LIA 1997).

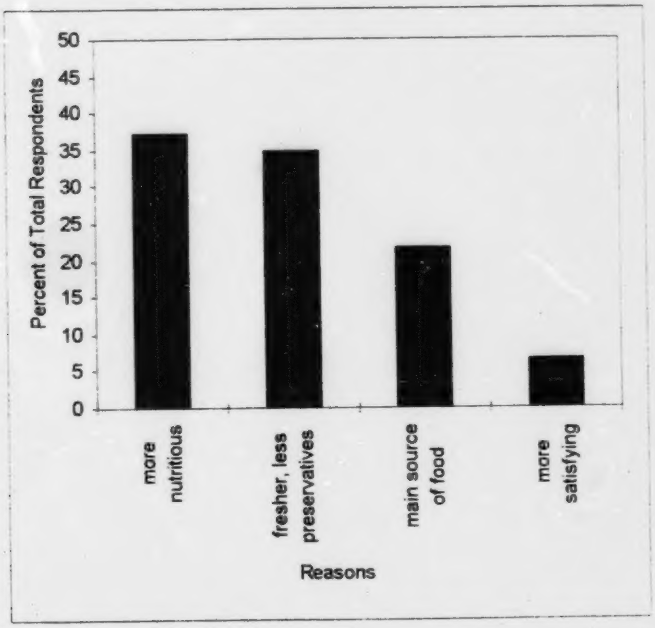

Figure 2. Reasons for country food preference over store-bought food among EHS respondents (N=176; LIA 1997).

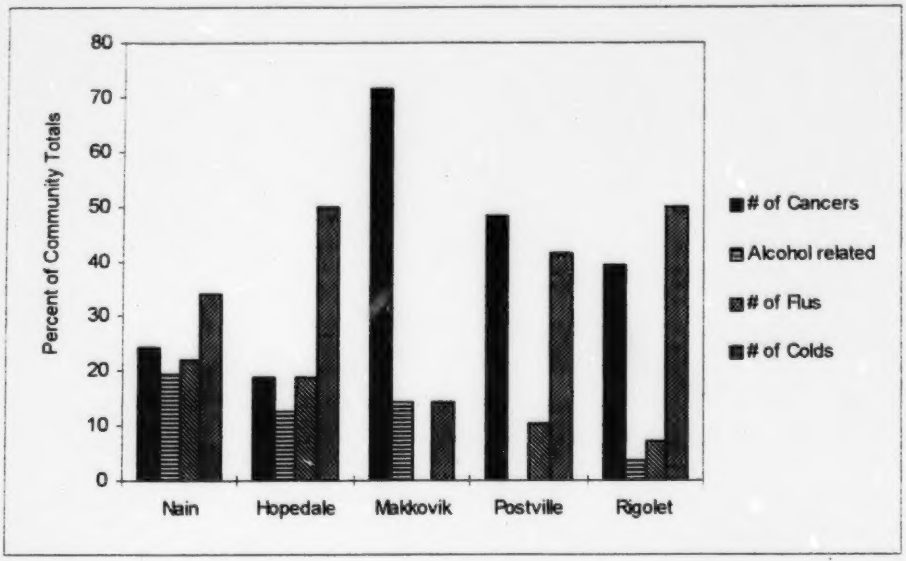

Figure 3. Most important community health concern in each Labrador community as reported by EHS respondents (Nain, N=82; Hopedale, N=16; Makkovik, N=7; Postville, N=29; Rigolet, N=28; LIA 1997).

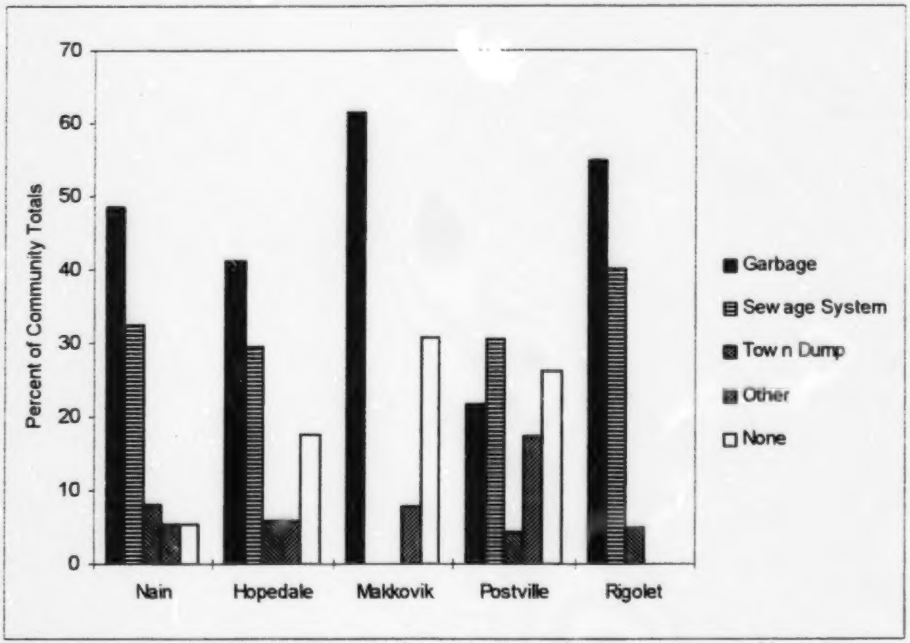

Figure 4. Most important community environmental concern as reported by Labrador community residents interviewed in EHS; "other" denotes concern for air pollution, helicopter traffic, and environmental impacts of mining (Nain, N=74; Hopedale, N=17; Makkovik, N=13; Postville, N=23; Rigolet, N=20; LIA 1997).

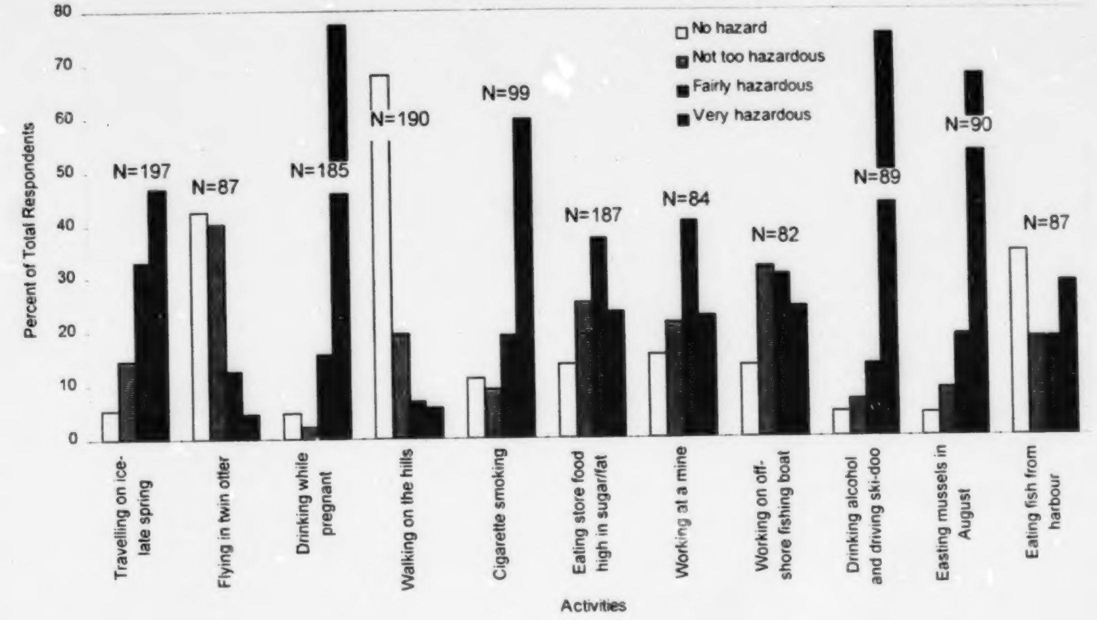

Figure 5. Level of risk associated with certain activities in Labrador communities, as reported by EHS respondents (LIA 1997).

health (Figure 5). "Eating fish from the harbour", and "walking on the hills surrounding the communities" were reported to not be hazardous by a large number of respondents in all communities (Figure 5).

CONCLUSIONS

The database developed from the Environmental Health Study conducted by LIA researchers in 1997 is a rich and detailed collection of Labradorimiut perspectives and concerns related to environment and health issues in the communities and region as a whole. Although there are great similarities between community concerns and perceptions, communities have unique local concerns and perceptions. These differences can be attributed to the community environmental and public health history and specific relationship to the surrounding land.

Expected Project Completion Date: This database is being utilized to investigate further questions regarding Inuit environmental health concerns in Labrador by local researchers and environment and health decision makers. It is expected that this process will be ongoing, however the majority of the re-analysis will be completed during the Fall of 1999.

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COMMUNITY PROGRAMS AND INFORMATION ON ISSUES OF CONTAMINANTS IN THE INUVIALUIT SETTLEMENT REGION

Project Leader: Billy Archie, Regional Contaminants Coordinator, Inuvialuit Regional Corporation, Aklavik, NT

Project Team: Jan Houseman, Inuvik Regional Health and Social Services Board; Val Walker, Aurora Research Institute; Community Health Representatives (CHRs) in Aklavik, Inuvik, Tuktoyaktuk, Paulatuk, and Holman

OBJECTIVES

The Inuvialuit Regional Corporation (IRC) hired a Regional Contaminants Coordinator:

1. To maintain an awareness of contaminants issues as they relate to the Inuvialuit and the Inuvialuit Settlement Region (ISR);
2. To provide information to and obtain feedback from communities on this topic; and
3. To assist the IRC in coordinating various projects funded under the Northern Contaminants Program (NCP).

DESCRIPTION

The Contaminants Coordinator's main role was to improve the line of communications between communities and researchers. The Coordinator arranged and organized several meetings with the *ad hoc* committees and coordinators from the projects funded through NCP (e.g. Inuvik Regional Human Contaminants Monitoring Program, CINE Dietary study).

ACTIVITIES IN 1998/99

Billy Archie from Aklavik, NWT was employed as the Regional Contaminants Coordinator in the Inuvialuit Settlement Region from October 1997- January 1999. During his tenure, he assisted the IRC with the following programs:

Contaminants Issues in the Inuvialuit Settlement Region

A proposal was developed by the IRC Contaminants Coordinator and submitted to the NCP for the 1998/99 fiscal year. The proposal was accepted and funds were provided to begin a communications plan for the Inuvialuit Settlement Area. Efforts were focussed on setting up *ad hoc* committees in each community, and hosting two meetings per year in order to update communities on present and ongoing studies on contaminants and as well to exchange information and bring forward any concerns raised by communities. A summer student was hired to assist the IRC Contaminants Coordinator to develop and distribute information packages for communities. These information packages included summaries from previous contaminants workshops/meetings, information on the nutritional importance of traditional foods, and monthly newsletters from the maternal cord blood study. A poster was developed and distributed to the communities with general information on contaminants: identifying what they are, how they arrive, how they are being dealt with, and who to contact for further information.

Numerous meetings were held at the community level with both the IRC Contaminants Coordinator and the summer assistant. During these visits, community *ad hoc* committees participated in discussions on implementing the projects mentioned below. All of the meetings were very productive, as the *ad hoc* committees were in support of all projects. Considerable assistance was provided by the members of the community *ad hoc* committees during the delivery of the projects.

Assessment of Dietary Benefits: Risks in Inuit Communities

This study was undertaken through the Centre for Indigenous Peoples' Nutrition and Environment (CINE) and Inuit Tapirisat of Canada (ITC). Four of the six Inuvialuit communities took part in the study. Field workers were hired in each community to assist a regional program coordinator hired by CINE. Questionnaires were designed at a workshop in October of 1997.

Prior to this, a pilot project was conducted at Shingle Point, Yukon; an ideal camp where Inuvialuit from Aklavik spend the entire summer fishing and hunting. The focus was specific to beluga muktuk consumption and the questionnaire was tested. Using this, the questionnaire was redrafted. Beluga muktuk was high on the priority list as previous studies indicated that levels of methylmercury in muktuk were on the increase. The results from the pilot project are held by CINE. The field work has been completed in all four communities and final results will be made available by March 2000.

The Contaminants Coordinator assisted the CINE regional program coordinator by providing contacts in, and an introduction to communities, travel and accommodation arrangements, and assisted with the hiring of field workers.

Inuvik Regional Human Contaminants Monitoring Program

This program was undertaken in collaboration with the Inuvik Regional Health and Social Services Board. Through a Maternal Cord Blood Study at the Inuvik General Hospital, the program measured the levels of contaminants present in mothers giving birth. The results are expected to be available in the year 2000.

The Contaminants Coordinator introduced the program coordinator to communities and *ad hoc* committees. He also ensured that the CHRs inform expectant mothers of the study and encourage their participation.

Front-line Training for Communicating about Contaminants and the Research Process

A training workshop sponsored by the Métis Nation - NWT, was held in Aklavik from March 10-12, 1998. This workshop was primarily designed for CHRs and Renewable Resource Officers, although workshop information was broadly circulated in communities along with general information about the NCP and the process for applying for funding from the program.

The Contaminants Coordinator assisted Métis Nation staff with travel and accommodations for all participants, assisted in the delivery of the course, and provided feedback from participants on information covered. The workshop focused on information in the *Canadian Arctic Contaminants Assessment Report* (CACAR) that was most relevant to the ISR. There were six participants, from the communities of Sachs Harbour, Paulatuk, Tuktoyaktuk, Aklavik, Arctic Red River and Fort MacPherson.

DISCUSSION/CONCLUSIONS

The overall Program has been educational and very informative for all participating communities. It has also been successful, focussing on awareness, and garnering community participation in all projects sponsored by NCP in the Inuvialuit Settlement Region. Through this, the IRC was able to obtain feedback from the six communities, and from this, begin work on developing a work plan to prepare for future work associated with the release of results from the studies conducted in the region.

The only difficulty encountered was the workload for the Contaminants Coordinator. We feel that in order for this position to be effective, it should be a full time position. Billy Archie resigned from the IRC Contaminants Coordinator position in January 1999. Lena Selamio of Tuktoyaktuk was hired in late February 1999 to replace Mr. Archie and spent the balance of the fiscal year familiarizing herself with contaminants issues in the ISR and establishing communications with community *ad hoc* committees and other key individuals.

Project Completion Date: ongoing

FRONTLINE TRAINING PROGRAM FOR NORTHERN COMMUNITY PROFESSIONALS

Project Leader: Joyce Bourne, Health Promotion Consultant, Kitikmeot Health and Social Services Board, Cambridge Bay, Nunavut

Project Team: Siu-Ling Han, Northern Contaminants Program, Department of Indian Affairs and Northern Development (DIAND), Ottawa; Judy Farrow, Environmental Director, and Miriam Tyson, Education Program Developer, Métis Nation – NWT, Yellowknife; Julia Ogina, Community Health Representative (CHR), Holman, NT; David Mablick, Nunavut Tunngavik Incorporated, Cambridge Bay, Nunavut

OBJECTIVES

The overall objective is to provide information, training and skills that will assist front-line community professionals with their ability to interpret, synthesize and communicate contaminants information and scientific research results which they receive. Subsequently, it is expected that they will pass on the information in a useful and informative manner to their communities in the Kitikmeot region.

Long-term

1. To create capacity in all communities in the Kitikmeot region with respect to basic knowledge of contaminants issues, knowledge of resources in relation to contaminants, and evaluation and negotiation of research proposals.

Short-term

1. To hold a three-day course on contaminants issues and research issues. Target participants will be front-line community professionals who may act as liaisons with researchers and their communities through their positions as CHRs, Renewable Resource Officers, Hunter and Trapper Organization (HTO) managers, or staff of local Aboriginal organizations.

2. To train a Kitikmeot instructor who will become a regional trainer for the course in the future.

DESCRIPTION

As more information about contaminants becomes available, it is expected that it will raise questions in the minds of residents of northern communities. For more information, guidance and/or interpretation of this information, residents are likely to turn to someone they know and trust living in their community. It is likely that professionals who have strong ties to, and reside in the community, may be asked to deal with contaminants information and/or research on contaminants.

In 1997/98, the Métis Nation – NWT and DIAND (Ottawa) developed a three-day training program for Northern Community Professionals. This course was intended to help those who were already in Health or Wildlife oriented jobs and who needed to understand more about contaminants in order to perform their duties. The course was pilot tested in Iqaluit and Aklavik.

In 1998/99, the course was offered in Yellowknife to participants from the Kitikmeot Region.

ACTIVITIES IN 1998/99

In the summer of 1998, consultation was undertaken in the Kitikmeot Region to seek the cooperation and support of the Kitikmeot Regional Health and Social Services Board, Nunavut Tungavik Incorporated and GNWT Resources, Wildlife and Economic Development (RWED), for the planning and delivery of a Frontline Training course for professionals in the Kitikmeot region. Although it was originally intended that the course be delivered in the Kitikmeot Region, it was eventually held in Yellowknife in November 1998. Yellowknife proved to be the best choice for both logistic and economic reasons.

Recruitment of participants, travel and accommodation logistics were handled by Joyce Bourne of the Kitkmeot Health and Social Services Board. An assistant instructor, Julia Ogina, a Community Health Representative from Holman, was recruited. A two-day training session for the assistant instructor was held in Yellowknife prior to the course delivery. The course took place on November 23-25, 1998 at the Yellowknife Inn, with participants coming from the Kitikmeot region.

The course was revised and delivered by Miriam Tyson, Education Coordinator at the Métis Nation – NWT. It addressed three main categories: 1) Contaminants Information; 2) Scientific Research; and 3) the Proposal Process. Participants received resource materials referenced to the Canadian Arctic Contaminants Assessment Report (CACAR; Jensen *et al.* 1997) and the Highlights of CACAR (Han and Adare 1997), as well as other sources of information on contaminants (e.g. AMAP 1997), particularly in Northern Canada.

RESULTS

Twenty-six people participated in the Frontline Training course and occasional observers dropped in during the course presentation. A list of full participants is found in Appendix 1.

The course provided an opportunity for networking and meeting other people who dealt with similar issues. Participants left with a greater understanding of the work that is being done on contaminants in the North. They will also be better prepared to evaluate and negotiate incoming research proposals in their community or area, and ultimately, to prepare their own community-driven proposals.

DISCUSSION AND CONCLUSIONS

The Frontline Training course for northern community professionals is a community 'capacity building' exercise, which, judging from participant reaction, needs to continue. During the course, there was lively interaction between the different professional groups. Most participants commented that this was a beginning, but there was a need for continued updating. On the whole, participants expressed a willingness to act as resource people in their communities.

During the planning for training course, it was determined that a team of two or three people should come from each community in the Kitikmeot. The strategy behind this was to initiate a team concept in the community for addressing contaminants issues and research concerns and proposals. It was thought that a team approach would be more successful for implementing community contaminants initiatives. Unfortunately, this did not happen when participants returned to their communities. A community strategy session (with outcomes and timelines) built into the workshop may prove more successful in the future.

The course needs to be revised and updated on a regional basis and may eventually be transferred to Nunavut and Aurora Colleges for delivery. Copies of the Instructor's Manual are available for review from the Métis Nation – NWT, Environment Division. The manual has been sent to the Council of Yukon First Nations (CYFN) and the Yukon Contaminants Committee.

Project Completion Date: The course for Kitikmeot participants was completed in November 1998. A revised version of the Instructor's manual has been prepared, based on comments from participant evaluation forms. Project work for 1998/99 is complete. In 1999/2000, the course will be offered to participants from the Kivalliq region.

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APPENDIX 1.

Frontline Training Course, November 1998
Kitikmeot Participants

Name	Position	Community
Jacob Keanik	Renewable Resource Officer	Gjoa Haven
Joe Ashevak	Renewable Resource Officer	Taloyoak
Colin Adjun	Renewable Resource Officer	Kugluktuk
Donna Kenneally	Environment Protection Officer	Kugluktuk
Monica Kapakatoak	Wildlife Technician Trainee	Kugluktuk
Brent Patterson	Regional Biologist	Kugluktuk
Mark Ekootak	Renewable Resource Officer	Holman
Wendy Avalak	Community Health Representative (CHR)	Cambridge Bay
Rosie Kagak	CHR	Kugluktuk
Julia Ogina	CHR	Holman
Rahabi Kamookak	CHR	Gjoa Haven
Roger Mannilaq	CHR	Taloyoak
Elizabeth Kayaksak	CHR	Pelly Bay
Nick Amautinuar	Secretary/manager, Hunter & Trapper Organization (HTO)	Pelly Bay
Martha Quqqiaq	secretary/manager, HTO	Taloyoak
Agnes Egotak	secretary/manager, HTO	Kugluktuk
Sara Kigeak	secretary/manager, HTO	Gjoa Haven
Ikey Evalik	secretary/manager, HTO	Cambridge Bay
Bessie Inuktalik	Resource Person	Holman
Ida McWilliams	Executive Director, HTO	Kugluktuk
Joyce Bourne	Health Promotion Officer, Kitikmeot Health & Social Service Board	Cambridge Bay
Bob Phillips	Environmental Health Officer Kitikmeot Health & Social Service Board	Yellowknife
Inuk Charlie	Nunavut Tunngavik Inc. (NTI)	Cambridge Bay
David Mablick	NTI	Cambridge Bay
Joani Kringayark	Renewable Resource Officer	Repulse Bay
Elsie DeRoose	Nutrition Consultant, GNWT	Yellowknife

THE SOCIAL REPRESENTATIONS OF CONTAMINATION IN THE NUNAVIK POPULATION

Project Leader: Dr. Éric Dewailly, M.D., Ph.D. Public Health Research Unit – Centre Hospitalier Universitaire de Québec (CHUQ) Research Centre and Laval University

Project Team: Suzanne Bruneau, Msc., Ph.D (in progress), Public Health Research Unit – CHUQ Research Centre;, Minnie Grey, Chairperson, Nunavik Nutrition and Health Committee, Public Health Department, Nunavik regional Board of Health and Social Services

OBJECTIVES

1. To evaluate information recall and attitudes towards consumption advisories on mercury.
2. To explore lay theories and lay knowledge about mercury contamination in the general population of Salluit

DESCRIPTION

Background

Between 1971 and 1978, Health and Welfare Canada (Medical Services Branch) carried out mercury exposure assessments in 350 native communities in Canada (Wheatley 1981, HWC 1991). Higher percentages of elevated blood mercury levels were found in Québec. Salluit residents, in particular, were found to have unexpectedly high levels. All participants in the survey received a letter containing mercury analysis results and recommendations. Individuals with high levels were told that these levels were caused by poisoned fish and that whales and seals might also be poisonned. According to Wheatley and Paradis (1995), news coverage of the problem by CBC radio with references to the Minamata disease intensified concerns in the community. Consequently, food consumption patterns were greatly disrupted in Salluit for some time because: "people stopped eating their traditional diet and as there were no available, affordable, acceptable food alternatives, a crisis situation resulted."

Further investigation in Salluit was undertaken with the cooperation of the Salluit Municipal Council, Kativik Regional Government and Makivik Corporation. The data to be collected (diet patterns survey, harvesting data, mercury levels analysis in country food species) were expected to provide the basis upon which recommendations could be made to the community about future consumption of country food. The food survey data, analysed with the mercury and harvest data, lead to the conclusion that the main source of mercury could be beluga and lake trout. In 1980, new recommendations were as follows: "... not to stop eating country food, but rather to eat as much as desired from the safe list." However, care was recommended with beluga, large trout, and liver from large seals. The latter recommendations applied especially to pregnant women, because the fetus is more sensitive than the adult to the effects of mercury.

Rationale

In 1992, in a communication presented at a workshop organized by Makivik Corporation, Peter Usher introduced the concept of "mercury gossip" (Usher 1992). At that time, he explained that when information is unclear, people tend to develop opinions and personal views on the subject that become a determining factor in influencing their behaviour. In 1995, Usher underlined that while Inuit are aware of the existence of contaminants, they often do not understand where they come from, how they reach the food chain and what are their health effects. This, again, generates "contaminants gossip" where the general population tends to generate its own information on sources and pathways of food chain contamination and possible health effects (Usher 1995).

Contaminants gossip, as described by Usher, can also be described as lay knowledge. Lay knowledge represents the essence of people's experience and is of great worth (Brown 1993, Stacey 1994, Phillimore and Moffat 1994). For many authors in the field of public health (Bibeau 1995, Massé 1995, Popay and Williams 1996) one of the most restrictive dimensions of the field is not taking into account lay knowledge. Many experts refuse to admit the fact that: "knowledge is organized in a system more or less integrated, and explanation and interpretation models of disease exist in the heads of people" (Massé 1995). These authors all insist on the fact that, with experience, lay people acquire a consistent knowledge, which is different but equal to the one held by public health experts. For Popay and Williams (1996), public health research has to develop new approaches and methodology built upon lay knowledge. It must take into consideration lay explanations for patterns of health and illness, disability and risk. Lay knowledge must be seen as a factor that shapes behaviours adopted by individuals when they are sick or when they try to avoid disease.

Hence, a few studies done on risk perceptions or social construction of risks in Nunavik have identified lay knowledge and lay theories about contaminants (e.g. Poirier and Brooke 1999, O'Neil *et al.* 1997a, 1997b). Studies on perceptions have contributed significantly to the comprehension of how food chain contamination and the associated risks are understood and interpreted by the Inuit population. Nevertheless, perceptions are individuals' opinions about attitudes and values. Using a social representation approach allows us to put in evidence ideas, rules and values not only of an individual, but of a social group. It offers a plausible model of how knowledge and meaning are shared, and why transformation and generation of knowledge must be a social process, not an individual one.

Communication is at the center of any social representation because it is by communicating that these representations are created. It is through human interactions that individuals will give a real sense to ideas or images that are driving their lives. A representation is a functional vision of the world, which allows the individual or the group to give a sense to its behaviour, to understand the reality through its own reference system, and to adapt to it and to define its place in it (Abric 1997). Therefore, social representations are not only cognitive, they are social, because if individuals define their representations because of their history and life context, they are also defining them in connection with the social system and social conditions in which they inscribe themselves.

ACTIVITIES IN 1998/1999

A research assistant helped prepare the content of the questions to be asked and was also responsible for interviewing the participants. The interviews were conducted in February and March, 1999. The original list of the 1978 survey, supplied by Medical Branch - Health Canada, contained 312 names. One hundred and eighteen participants were excluded either because they had died or because they were no longer residents of Salluit in 1999. Finally, 194 individuals were invited to participate in the survey and a total of 140 (72.2%) agreed to participate. Furthermore, 4 other individuals who were interested in knowing their blood mercury levels participated in the survey on a voluntary basis. These last participants were excluded from the present survey because they did not participate in the 1978 survey. Finally, 2 participants were excluded because they refused to answer to our survey.

RESULTS AND DISCUSSION

Forty-three percent of the participants were in the 18-39 years age group, 34% in the 40-59 age group, and 23% in the 60+ age group. Women represented 63% of the total participants. The mean age of participants was 45.5 years old, and ranged from 20 to 79 years old. In 1978, the mercury levels analysis included newborns. It seems logical to exclude from this analysis individuals who were too young to recall anything about any events that happened at that time. Therefore, we decided to exclude from the results that concern information recall, all participants (n=16) who were 30 years or under in 1998.

Information recall

To the question: "Do you recall participating in the 1978 Health Canada survey on mercury in 1978?", 68.9% answered 'yes' and 31.1% answered 'no'. To the question: "How did you learn that high levels of mercury were found in Sallumiut who participated in the Health Canada survey in 1978?", 36% did not recall how they learned about high levels of mercury. Among those who recalled, 35% said that they learned from nurses, 28% said that they were told by other people in the community, 18% heard from the Health Canada survey team, 8% from the FM radio station and 1% from the teacher at school.

Surprisingly, nobody could answer to the following question: "After the survey results were out, what did the health authorities tell you or your family about the health risks linked with the consumption of fish and marine mammals contaminated with mercury?" People recall recommendations about eating less fish or marine mammals but they say that they had never heard about health risks. To the question: "What was your family's reaction to the announcement that some people participating in the Health Canada Survey had high levels of mercury in their hair or blood?", 37% did not recall. Among those who recalled, 45% said that they had no reaction to this announcement. People who reacted said that they decreased their consumption of marine mammals and/or fish and started buying more store food, but most of them said that after a while, everything came back to normal and they started to eat regional food again without worry.

To the question: "Following the findings of high levels of mercury ... do you recall any changes in the fishing or hunting habits of the Sallumiut?", 66% did not recall. Among those who recalled, 57% said that there were no changes in fishing or hunting and 38% said that there was a decrease in fishing and/or hunting. To the question: "Following the findings of high levels of mercury ... what were the changes noted in the diet of Sallumiut?", 45% of respondents did not recall. Among those who recalled, 39% said that there were no changes in the diet and 61% said that there were some changes in diet. The changes noted by the participants are various and are not necessarily in accordance with the recommendations that were made at that time by Health Canada. Overall, all fish and marine mammals were pinpointed and nobody seemed to recall that recommendations applied particularly to pregnant women.

To the question: "Now in 1999, would you say that eating a lot of regional food is: very good for my health; quite good for my health; not that good for my health; has been good for my health but is not anymore?", 71% of respondents think that regional food is very good for their health, 24 % think that it is quite good for their health, and 5 % say that it is not that good. Finally, when we asked if they were worried about mercury contamination at the present time, 62% of the participants indicated that they are not worried about mercury contamination, 14% are definitively worried and 24% are a little worried and are anxious to get their results of mercury body burden.

Social representations

One important process that generates social representation is called "anchoring". According to the theory, the process operates by making the unfamiliar seem familiar. Anchoring is the mechanism which strives to anchor strange ideas, to reduce them into ordinary categories and images, to set them in a familiar context (Moscovici 1984). It reduces the threat of the unfamiliar by providing familiar classifications and names. The process of "anchoring" was highlighted by the following question: "When I say mercury contamination what does it make you think of (say anything that comes to your mind)?"

In our survey, 46 individuals answered either that they think nothing about mercury contamination or that they don't know what mercury is anyway. These participants have the greatest rate of response «don't recall» to any question. Their mean age is 39 years old, meaning that their mean age in 1978 was 19 years old. There were many individuals who were too young to recall anything linked with the 1978 survey or about mercury in the food chain. It is evident that there is a lack of information concerning mercury contamination in young adults of Salluit and that it will be important when results of the 1998 study are available to develop educational and informative tools adapted to their specific needs.

Bug/bacteria/germs/worms: Thirty-one respondents answered this question saying that it makes them think of a bug, bacteria, germ or a worm. Most of these respondents were saying that either it is circulating in their bloodstream or that it does not belong in the body. For example: "I think of a bug in the body that is not supposed to be there"; "I think of a bacteria that is causing sickness"; "I thought that mercury was a little white bug with lots of legs who run around my bloodstream. I don't know why but that's how I imagine it"; "I think about a worm that eats around in our bloodstream". The mean age of this group is 54 years old. This representation of mercury suggests that people could mix up mercury contamination with trichinosis in walrus since Trichinella spiralis is a roundworm. One has to consider that, between 1982 and 1987, five outbreaks of trichinosis were documented in Nunavik and they all happened in Ivujivik and Salluit (Grondin et al. 1996). Furthermore, a monitoring program of Trichinella in walrus is ongoing in Salluit since 1992. Therefore, trichinosis is still an actuality in Salluit and it is more than possible that older individuals think that any food chain contamination is cause by something that is similar to the presence of Trichinella in walrus. Once again, it will be important to explain to the population that contaminants such as mercury are not infections that can be transmitted from animals to humans, that it builds up in the tissues of fish and humans and stays there for a very long time.

Thermometer: Twenty-five participants thought of the mercury found in a thermometer when they think of mercury contamination. The mean age of these respondents is 48 years old. One can ask where this idea came from. Some respondents said: "I think of thermometer because the people who talked about it in 1978 compared that kind of mercury in our bloodstream" others said: "I remember that me and other people were told the mercury is like the mercury in the thermometer"; "I think of the mercury in thermometer because I heard that before". Some questions come to mind: was the idea of the mercury in a thermometer really used to explain to the population what mercury was? This would be surprising but it is possible that the nurses explaining to individuals what mercury is made the parallel between mercury in the food chain and mercury in a thermometer. In turn, these individuals explained to members of their family or friends what they had been told. It will be important when the results of the 1998 survey are given back to the population, to clarify that the kind of mercury that accumulates in the fish, marine mammals or humans has no similarities with the mercury found in the thermometer.

Health effects: A total of 17 participants did not have a clear representation of mercury contamination but described it as something that should not be in their bodies or something that could harm them. For example, respondents said: "Something dangerous or bad for my body"; "I think of something contagious or dangerous"; "Mercury might do something to me like to change my body crippled or handicapped"; "Something that can cause sickness or make a person crippled". Our expectations to have the respondents talk about health effects was higher since the article published by Wheatley and Paradis (1995), stated that news coverage of the problem by CBC radio and national news with references to the Minamata disease intensified concerns in the community. Two hypotheses can explain the lower than expected number of responednts who spoke about health effects: 1) Following the 1978 survey, a risk management campaign was initiated by Makivik Corporation which, as Usher *et al.* (1995) concludes, allayed fears of serious ill-health effects associated with consuming country food and gave residents a more balanced perspective on mercury contamination; 2) Recently, O'Neil *et al.* (1997b) stated that some older informants say that a resistance to the discourse of contaminants exists because one of the principles of Inuit thinking is that to think, talk or worry about something might cause more problems. For example, if one talks too much about the animals, they might disappear. The same way of thinking can apply to disease; one should ignore talking about that subject to avoid sickness.

One interesting aspect that came out when comparing the first (bug/bacteria) and second group (thermometer) concerns the appreciation of regional food. Sixty-three percent of respondents in the first group say that the regional food is very good for their health compared to 76% in the second group. Since there are more older individuals in the first group, one could expect that they are the ones who rely mostly on regional food and most of all consider this food as essential to their lives. It is difficult at this point to conclude why older individuals are changing their visions about their native food but it is something to explore in the near future. Meanwhile, it is interesting to note that in 1978, 25% of respondents in the bug/bacteria group changed their personal diet, fearing the mercury contamination of the food chain.

CONCLUSIONS

Social representations are always elaborated in the course of communication that puts in perspective phenomenons of diffusion, propagation and propaganda (Doise 1986). Dissemination of information is often characterized by a lack of differentiation between the source of the message and the receiver. One of the first goals of communication should be to create a knowledge that is common to the two groups in presence (experts and lay persons). Consequently, it is essential to take into consideration lay knowledge. The information compiled in this survey gives us indication that 20 years after the first survey (Health Canada), information on mercury contamination of the food chain is more or less integrated and possibly associated with other situations of contamination already present in Nunavik. A lack of appropriate information adapted to the different age groups can possibly contribute to influence health- and nutrition-related behaviour. These findings will help prepare the next information campaign linked with the return of results of the 1998 survey.

Project completion date: March 31, 1999

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CONTAMINANT EDUCATION PROGRAM FOR NORTHERNERS: SCHOOL PROGRAM FOR NWT SCHOOLS

Project Leader: Judy Farrow, Environmental Director, Métis Nation - NWT, Yellowknife, NT

Project Team: Miriam Tyson, Education Program Developer, and Sarah True, Research Assistant, Métis Nation - NWT, Yellowknife; Steven Daniel, Science Coordinator, and Fiona O'Donohue, Director, GNWT Education, Culture and Employment, Yellowknife; Siu-Ling Han, Northern Contaminants Program (NCP), Department of Indian Affairs and Northern Development, Ottawa; Marianne Bromley, Education Consultant, Yellowknife

OBJECTIVES

Long-term:

1. To provide Northerners with information regarding health risks from anthropogenic and natural contaminants that are present in Northern food chains, and the necessary tools to make informed decisions in their food use.
2. To develop materials to assist communication and interpretation of the technical aspects of the NCP to communities in northern Canada through the NWT school system.
3. To create capacity in all northern communities to deal with contaminant information and participate fully in the research process.

Short-term:

4. To promote NCP Junior High and High School Science Programs in NWT schools.
5. To develop an outline for NCP lesson plan development for NWT Social Studies 7, 8, 9 and High School Northern Studies.

DESCRIPTION

The School Program for NWT Schools project brings information that will assist informed decision making by individuals and communities in their food use, to the grass roots level, through schools and community learning centres. The Métis Nation Contaminant Education Program develops and integrates contaminant-related program materials with existing NWT school curricula. The program materials are cross-referenced to the relevant curricula and, wherever possible, to *Dene Kede* and *Inuuqatigiit* — documents that explore the school curricula from the Dene and Inuit perspectives. They are intended to reflect or validate the traditional point of view, wherever possible.

These educational materials will educate those young adults who, in the near future, must make their own decisions on the subject of contaminants and traditional/country food. Children who are educated about contaminants at school often go home and tell their parents what they have learned. We can teach the adults through the children. Designing materials that fit into the required school curriculum means that the issue will be addressed in an ongoing basis. As students move through the school system, the issues will be dealt with at a more sophisticated level.

The main source of information for the development of this education program has been the research funded by the Northern Contaminants Program (see Jensen *et al.* 1997, Han and Adare 1997, AMAP 1997).

ACTIVITIES IN 1998/1999

New work, begun in 1998/99, looked at the development of lesson plans for Junior High Social studies for grades 7, 8 and 9 and senior high Northern Studies. In the past, our school program has concentrated on materials compatible with science curricula. However, some aspects of the NCP cannot be adequately addressed through the science curriculum. For example, the need for international negotiations to achieve global control of contaminants and the role of Northern Aboriginal organizations in this process can best be addressed through the Social Studies curriculum. At the senior high level, Northern Studies is a required course for all NWT students, and provides an ideal vehicle for teaching the social sciences aspects of the NCP.

In order to develop a thematic outline for lesson plans, the Social Studies curriculum was cross-referenced with NCP information. The thematic approach is being adopted to accommodate the division of the NWT into two new territories; it is anticipated that Nunavut will eventually have its own curriculum and a thematic approach will be more adaptable. New curricula need to be phased in gradually so as not to disrupt the progress of students. The existing NWT curriculum will continue to be used in 1999/2000. Teachers and education officials from all regional education authorities were surveyed to help with ongoing planning and format for lesson plans.

As well as the new programming, we have continued to respond to requests for our educational materials. Hard copy is still the most desired format, but also the most expensive.

RESULTS

To date, the School Program for NWT Schools project has produced the following (see also Appendix 1):

- A database of NCP contaminant research, school reference materials, community profiles and Health Risk Assessments;
- Junior High Books have been distributed to Schools, School Board Regional Resource Centres in the Northwest Territories, Aurora Research Institute and Nunavut Research Institute;
- Program materials for Grades 10 and 11, NWT Science 15 and 25, distributed to all NWT schools offering those grades;
- The overview booklet entitled 'Contaminants in Northern Canada', is available for educators, professionals working in the contaminant field as well as the general public;
- Draft outline for developing lesson plans for Junior High Social Studies and Senior High Northern Studies; and
- Hard copy has been converted to PDF and HTML format.

DISCUSSION/CONCLUSIONS

Generally, the reaction to the program has been very positive. Requests for the schoolbooks have exceeded the quantities available, although we continue to supply Xerox copies or CD-ROM versions. The preference expressed by teachers is for hard copy materials. Some are still reluctant to use CD-ROM or Internet; in some cases it is because the school does not have the facilities or the budget to access materials in this way.

In the last two years, there has been a high turnover of teachers, particularly at the junior high level. The result is that teachers often take their manuals with them and the new teachers are not aware of our materials. Distribution via the Internet may prove useful. Many schools have disbanded their libraries because of budget cuts, so the copies are 'lost'.

The experience of the past year demonstrates the importance of in-service training with classroom teachers and the development of an ongoing distribution system. In 1999/2000, there will be a greater emphasis on holding workshops with teachers, which we hope will alleviate the distribution problem. Books and CDs will be distributed at the workshops. In response to our survey, teachers indicated a need for the kind of materials that we have produced.

Expected Project Completion Date: Outlines for the Social Studies and Northern Studies lesson plans are complete, and development of the lesson plans will take place in 1999/2000 (see also Appendix 2 for five-year plan).

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APPENDIX I

The following school materials are available on request from the Métis Nation - NWT.

1. NCP Overview Booklet

This fifteen page, illustrated booklet, written in plain language, contains a straightforward explanation of the sources and effects of contaminants in the North. It covers contaminants in general, their effects on wildlife and possible effects on human health. It includes a discussion of the various programs in place to study contaminants in the North. As well, the booklet provides a list of ways that people can learn more about the Northern Contaminants Program (NCP). The booklet has been made available to NCP agencies, partners and the general public. It has been reprinted twice.

2. Junior High Science Lesson Plans

Lesson plans are designed to fit a particular unit within the curriculum. In the manuals, teachers are introduced to the Arctic Environmental Strategy (AES); Northern Contaminants Program then guided to the appropriate curriculum unit. An overall view of lesson plans and sequence are provided to aid teachers in scheduling and preparation. A chart is used to guide teachers to the curriculum unit where the lesson plans can be used.

Title	Contaminants in Northern Canada. Lesson Plans for Grade 7 Science 1. Environmental Concerns 2. Nuclear Energy.
Date	1995
Format	Spiral bound teacher's manual.
Description	Background information on AES: NCP, lesson plans and student activities referenced to the required NWT Science Curriculum. Spiral bound to allow easy copying of student activity sheets. Sets of overhead transparency masters are also included. Lists ways to access more information about NCP.
Length	144 pages
Community	Applicable to all NWT communities offering grade 7.

Title	Contaminants in Northern Canada. Lesson Plans for Grade 8 Science 1. Northern Food Chains and Webs 2. Pulp and Paper.
Date	1995
Format	Spiral bound teacher's manual.
Description	Background information on AES: NCP, lesson plans and student activities referenced to the required NWT Science Curriculum. Spiral bound to allow easy copying of student activity sheets. Sets of overhead transparency masters are also included. Lists ways to access more information about NCP.
Length	108 pages
Community	Applicable to all NWT communities offering grade 8.

Title	Contaminants in Northern Canada. Information for Science Teachers Grades 7, 8 and 9.
Date	1996
Format	Spiral bound teachers reference manual.
Description	Background information on AES: NCP, curriculum guide, guides teachers to where NCP information may be used with the required curriculum. Reference lists of NCP projects, listed by species being studied and references section on contaminants. Lists ways to access more information about NCP.
Length	58 pages
Community	Applicable to all NWT communities offering grade 7, 8 and 9

3. SCIENCE 15 AND SCIENCE 25 HIGH SCHOOL LESSON PLANS

Programs have been developed for the new NWT integrated science curriculum. NWT Science 15-25 (New) is an integrated science program that allows students to meet the credit requirements for a High School Diploma. The focus is on helping students understand the scientific principles behind the natural events they experience and the technology they use in their daily lives. It is designed to develop in students the knowledge, skills and attitudes to help them become capable of and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities. A key component of this new curriculum is the demonstration of connections between science, technology and society.

Title	Contaminants in Northern Canada. Lesson Plans and Reference Materials for NWT Science 15 and NWT Science 25.
Date	March 1997.
Format	CD - ROM and quick print hard copy on 3-hole paper.
Description	Background information on AES: NCP, lesson plans, and student activities referenced to the required NWT Science 15 and 25 Curriculum. CD - ROM format provides the opportunity to access reference information by computer or provide hard copy print out capabilities. Reference materials and appropriate graphics are provided to assist teachers. Lists ways to access more information about NCP.
Length	650 MB
Community	Applicable to all NWT communities offering grade 10 and 11.

APPENDIX II

Métis Nation - NWT Northern Contaminants Education Program NCP Phase II Five Year Plan

1997-98

Environmental Studies 35 develop draft lesson plans
Develop and pilot Frontline Training Program

1998-99

Social Studies 7,8 and 9, Northern Studies develop outline for lesson plans
Distribute school materials on request.
Review and modify Frontline Training Program for Kitikmeot delivery
Train Assistant Instructor from Kitikmeot Region to aid in delivery of Frontline Training Program

1999-00

Teacher workshops
Distribute school materials
Lesson plans for Social Studies, Northern Studies
Negotiate distribution via GNWT ECE website
Frontline Training for Kivalliq region.

2000-01

Publish Social Studies and Northern Studies
Review background materials
Develop multimedia on line presentations

2001-02

Develop on line resources for teachers and community professionals
Final report

TRADITIONAL KNOWLEDGE RESEARCH GUIDELINES

Project Leader: Norma Kassi, Contaminants Coordinator, Council of Yukon First Nations (CYFN)

Project Team: Yukon Fish and Wildlife Management Board, Development Assessment Process; Yukon Heritage Resources Board; Yukon Territory Water Board; Yukon Salmon Subcommittee; Yukon Contaminants Committee; CYFN Implementation Department; Elders Council; Dene Cultural Institute; Yukon Territorial Government

DESCRIPTION

The Traditional Knowledge Research Guidelines will set out methods for the collection, storage, access, use and ownership of Yukon First Nations' traditional knowledge (TK). It will enhance researchers' knowledge and skills when seeking traditional knowledge by providing them with guidelines developed by Yukon First Nations, regarding proper protocols to follow. This guideline is intended to ensure that positive working relationships are developed between the scientific community and traditional knowledge holders.

ACTIVITIES IN 1998/99

In December 1998, a planning session was held in Whitehorse at the Council of Yukon First Nations. The goal of the planning session was to create a working document on traditional knowledge research guidelines. There were 60 participants representing Yukon First Nations, Boards and Committees, Yukon College, Yukon Archives, and the Federal and Yukon Governments. This planning session was a significant event for many of the participants because many of the organizations that they represent wanted to incorporate TK into their work but were unsure of how to proceed. This forum gave these organizations the opportunity to begin that process.

Barney Masazumi, Director, Dene Cultural Institute, was instrumental in facilitating the process. He assisted the participants in identifying four key topics for discussion which were addressed in break-out sessions: 1) The use of TK; 2) Access to TK; 3) Storage of TK; and 4) Collection of TK.

RESULTS AND DISCUSSION

Some of the concerns that participants felt were very important with respect to the four key topics are outlined below:

Use of TK

Participants felt that it was necessary to respect the wishes of the Elders concerning the use of traditional knowledge. Certain aspects of TK may be used whereas certain other aspects may not be used. Language and culture must be respected. Some of the traditional knowledge information and materials are very sensitive and there are strong spiritual aspects that go hand-in-hand with the knowledge. First Nations communities should be the ones deciding who can use their knowledge, as it is a privilege and must be respected. Traditional knowledge is a decision-making tool and its usage must be protected.

Access to TK

Access to traditional knowledge is a privilege given to researchers and therefore must be respected. A screening process should be developed which takes into consideration community consent. Interpretation is also a very important issue when giving TK access to a researcher. They must ensure that the wisdom of Elders and TK holders is properly conveyed.

Storage of TK

There is a need for a First Nations archive to store artifacts and information in order to protect private information. Whether there should be a central storage facility or whether each community or First Nation should have their own facility is still to be worked out. First Nations need to consider what are the archival storage options (e.g. computers/CD ROMS, GIS, a central building). First Nations may want to look into developing partnerships for pursuing options for storage facilities.

Collection of TK

There is no need to reinvent the wheel. Guides for conducting oral history projects already exist. First Nations have used their own First Nation people to record and interpret oral stories, legends, and observations about the animals and land.

Each community should be responsible for guidelines at the community level. First Nations need to set up a process that respects oral tradition. The quality of information is greater when conveyed in person when it comes to language and culture. But, how do we validate a type of knowledge without writing it down? There is a fear of loss of meaning when writing down the information. Some components of language cannot be translated from one language to another.

First Nations' community members should conduct information collection at the community level. Traditional knowledge holders are experts in their areas and should also be compensated accordingly. The sources of TK information must be referenced in any work being conducted. The 'intent' of collection, as well as who will benefit, must be made clear.

CONCLUSIONS

Each of the participants were tasked with taking the information back to their First Nation for input towards the development of a Yukon First Nations traditional knowledge guideline.

The key outcomes were:

- an *ad hoc* steering committee was struck to bring guidance to the planning session;
- a document was drafted from the meeting for the participants to take back to their communities in order to begin discussions on a traditional knowledge guideline; and
- a draft guideline was developed from the comments at the workshop and feedback from the communities. A guideline is expected to be completed after TK Planning Session II, to be held in Whitehorse, October 13 and 14, 1999.

Expected Project Completion Date: March 2000

COMMUNICATION, EDUCATION AND COMMUNITY-BASED STRATEGIES FOR THE AKAITCHO TERRITORY

Project Leaders: Styd Klugie, Regional Contaminants Coordinator; Akaitcho Territory Tribal Council

Project Team: Deninu K'ue First Nation; Lutsel K'e First Nation; Yellowknives Dene First Nation (Ndilo and Dettah); Salt River First Nation; Fort Fitzgerald First Nation; Lands and Environment Department, Dene Nation; Contaminants Division, Department of Indian Affairs and Northern Development (DIAND) NT

OBJECTIVES

This project is intended to provide a vehicle for two-way communication of NCP information and contaminants issues. The project objectives are:

1. To promote and organize networking at the community and regional levels concerning environmental issues.
2. To identify, prioritize and support environmental issues brought forward by the communities.
3. To bring the results of scientific studies completed in the North to the communities in an understandable format.
4. To translate scientific terminology, as identified by the communities, into their respective languages (i.e. Dogrib, Chipewyan and Cree).
5. To promote traditional knowledge as a valuable contribution in the study of northern environmental concerns and issues.

DESCRIPTION

The Akaitcho Territory Government and First Nations are continuing to expand and develop their involvement in environmental issues in the Akaitcho region. As current and ongoing concerns pertaining to environmental status are addressed, First Nations are taking a more active role in protecting, preserving and sustaining the natural environment and wildlife. In addition, environmental health issues are arising in the region, and these health concerns are brought forward and addressed by the Northern Contaminants Program's Regional Contaminant Coordinator, Contaminants Division (DIAND), and GNWT Health and Social Services through workshops and conferences.

The Regional Contaminants Coordinator (RCC) assisted the Akaitcho Territory First Nations in developing materials and informing people about contaminants and environmental projects concerning human health and contaminants in traditional foods. The dissemination of information was directed to all First Nations of the Akaitcho Territory Government.

ACTIVITIES IN 1998/99

The following is a list of Northern Contaminants Program (NCP) related activities in which the Akaitcho RCC participated:

- Attendance at the NWT Environmental Contaminants Committee (ECC) workshop in Iqaluit, NT, December 3-5, 1998. The concerns expressed at the workshop were primarily Eastern Arctic concerns. It was pointed out at the workshop that Traditional Knowledge was important to the NCP and would be considered as a meaningful part of proposals.
- Participated in conference calls concerning the planning and review of contaminants projects and research in the NWT; voiced Akaitcho Territory issues and concerns.
- Developed and submitted the Akaitcho Territory RCC proposal for 1999/2000, in consultation with Contaminants Division personnel; in total, there were four proposals from Akaitcho Territory First Nations for the 1999/2000 fiscal year.
- Reviewed and evaluated NCP proposals for 1999/2000, as part of the NWT ECC, in Yellowknife, February 9-11, 1999.
- Organized the Akaitcho Regional Contaminants Workshop, held in Fort Smith on February 19, 1999 (see below).

Table 1. Summary of Presentations.

Speaker	Topics
David Kennedy	• overview of the NCP • Contaminants Division and DIAND • contaminants definitions • NCP projects in the region
John Nishi	• contaminants and wildlife
Bart Blais	• Slave River Environmental Quality Monitoring Program • brief introduction of methods and results • recommendations on further monitoring
Dr. André Corriveau	• cancer and contaminants • other health determinants • cancer trends in NWT and Canada
Maurice Boucher	• contaminants in beaver and muskrat of the Slave River Delta

Other environment-related activities included:

- Participation in First Nation Forestry Program.
- Attended a presentation of a Protected Areas Strategy for NWT in Yellowknife.
- Helped prepare a proposal for the Community Animation Program '98.

THE REGIONAL WORKSHOP

The purpose of the Akaitcho Regional Contaminants Workshop, held in Fort Smith on February 19, 1999 was to communicate with all the Akaitcho Territory communities, inform them of NCP projects and allow people to voice their concerns. Workshop participants are listed in Annex 1.

The workshop consisted of presentations on the NCP in general and specific projects on contaminants in Akaitcho Territory, along with any questions that arose during the presentations (Table 1).

Concerns from the community representatives were voiced at the workshop, several of which are contaminants-related:

- health advisories are based on assumptions; contaminants are tested on animals
- statement that information was given at the time of the crash of Cosmos 954 (the Russian satellite which crashed in the NWT in 1978) that there would be health problems; radiation projects in Lutsel K'e and Baker Lake looked for leftover radiation but is was not found
- causes of sickness and death in people
- airborn pollutants and the burning of community garbage
- fish in Stark Lake - perception that fish are not in as good a shape and not as abundant
- fish migration from Slave River and Great Slave Lake and sediment accumulating at the lower Slave River
- abnormalities in Slave River burbot liver (from Bart Blais' presentation) and the importance of continued monitoring on the Slave River
- bird migration and contaminants
- anthrax as a biological disease
- accumulation of contaminants at Fort Resolution Bay
- need for a community database to know what is in the environment
- need for Dene translation of reports and projects

Expected Project Completion Date: A contaminants glossary and the workshop notes are being translated into Chipewyan, Dogrib and Cree. This is expected to be completed in September 1999.

Annex 1. Akaitcho Regional Contaminants Workshop Participants

Name	Organization
David Kennedy	Contaminants Division, DIAND
John Nishi	Resources, Wildlife and Economic Development, GNWT
Dr. André Corriveau	Chief Medical Health Officer, GNWT Health and Social Services
Bart Blais	Water Resources, DIAND
Maurice Boucher	Fort Resolution Environmental Working Committee, DKFN
Allison Armstrong	Lands and Environment, Dene Nation
George Martin	Yellowknives Dene First Nation Dettah
Archie Catholique	Lutsel K'e Dene First Nation
Augustine Enzoe	Lutsel K'e Dene First Nation
Alfred Liske	Yellowknives Dene First Nation
Louie Martin	Yellowknives Dene First Nation Ndilo
Mike Francois	Yellowknives Dene First Nation Ndilo
Chief Don Balsillie	Deninu K'ue First Nation
Richard Simon	Deninu Community Council, Fort Resolution
Mark Bradly	Wood Buffalo National Park
Marnie Copper	University of Saskatchewan veterinary student
Denise Lowing	University of Saskatchewan veterinary student
Styd Klugie	Akaitcho Territory Government

A FIVE-YEAR STRATEGY OF COMMUNICATION AND ACTION ON CONTAMINANT ISSUES IN THE CANADIAN ARCTIC

Project Leader: Eric Loring and Scot Nickels, Inuit Tapirisat of Canada (ITC); Billy Archie, Inuvialuit Regional Corporation

Project Team: Inuvialuit Regional Corporation; Centre for Indigenous Peoples' Nutrition and Environment (CINE); Inuit Circumpolar Conference (ICC); NWT Environmental Contaminants Committee

OBJECTIVES

Some of the obligations that were required of the Regional Coordinator for the Inuvialuit region last year included:

1. To achieve a level of understanding about the concerns and questions that Inuit have in relation contaminant issues, and to communicate up-to-date, understandable information about contaminants.
2. To provide a forum for responding to and facilitating interactions within and between communities with regard to contaminant issues, and to facilitate the link between communities, the Northern Contaminants Program (NCP), and NCP scientists.
3. To build capacity in as many Inuit communities as possible, to effectively communicate community concerns and priorities with regards to contaminants to other decision-making bodies at the regional, national and international levels.
4. To mobilize, build and enhance partnerships between community members and regional organizations, and the scientific community.

DESCRIPTION

There is growing recognition among public authorities of the importance of communication of contaminants information, but there is as yet little understanding of how best to go about it. Miscommunication of contaminants information in Inuit communities in the past has led to certain degrees of alarm, apprehension and mistrust within Inuit communities. Such communication was largely *ad hoc*, neither carefully planned nor well coordinated. Most of this information was fragmentary, lacking local context and not surprisingly, often wrong and misleading. As a result, action taken in response to contaminants information was often ineffective in safeguarding personal health and led to a general distrust of outside experts.

The NCP, working together with ITC and other Aboriginal organizations, attempted to alleviate this distrust with an efficient exchange of contaminant information between scientists and government officials and people at the community level. The hiring of regional contaminants coordinators enhanced ITC and ICC communication efforts by working from the ground level up and developing a cross-pollination of ideas – at least informally – at the regional and inter-regional levels. Communication of information about contaminants and their effects needs to be well coordinated, consistent and timely. The job of the regional contaminant coordinator is one of developing stronger partnerships that are based on trust and equality. This is an important step in eliminating the growing apprehension among Inuit population.

The regional contaminants coordinator (RCC) from the Inuvialuit Region, working with ITC, acted as a conduit for two-way information exchange between the communities of Inuvik, Aklavik, Holman, Sachs Harbour, Tuktoyaktuk and Paulatuk and the NCP. The RCC kept in constant contact with these communities, either by in-person meetings or via conference calls. In all communities, there was a pervasive unease and anxiety about contaminants. Frequent concerns raised by the communities were: "Is our food safe to eat? Do contaminants cause cancer? Are contaminants the cause of unexplained deaths and abnormalities in animals and fish? Are they the cause of unexplained illness with humans? How do contaminants affect our children?" The RCC was able to address these concerns with accurate, timely and accessible information in layman language and/or local dialects to a broad spectrum of community members. Otherwise, most of these concerns may have gone unanswered and indeed unknown if it were not for the groundwork of the RCC. Also, the RCC was instrumental in bringing keen observations and experiences with wildlife, which the Inuit of this region possess, to the scientists involved in contaminants research.

The RCC also responded to local information requirements about contaminants (using, as necessary, contacts at National Aboriginal Organisations, NWT ECC, Department of Indian Affairs and Northern Development (DIAND) contaminants unit, NCP scientists, etc.). Responsibilities also included facilitating the communication of community concerns and ensuring that relevant regional and community organisations were kept informed and that their input is brought back to the NCP through schedules meetings with the NWT ECC.

ACTIVITIES IN 1998/99

The Inuvialuit Regional Contaminant Co-ordinator was involved in the following projects:

1. The *Human Contaminants Monitoring Program* which has been implemented by the Inuvik Regional Health and Social Services Board. The Program's objective is to establish baseline information on organochlorine and metal contaminant levels in blood and mercury in hair. This is part of the maternal cord blood and hair sampling program. The RCC made sure that the participants in this study understood the significant of such a study and assisted the Health and Social Service Board with any inquiries.

2. The *Assessment of Dietary Benefit-Risk in Inuit Communities* study spearheaded by CINE, involving the communities of Aklavik, Tuktoyaktuk and Paulatuk. RCC duties included facilitation between communities, researchers and CINE. The RCC also helped to inform local researchers who were involved in this project on contaminants and their role in this project. It is safe to say that the high involvement in this project rate in this region was due to the RCC's efforts in preparing the communities before the scientists arrived.

3. Community *ad hoc* Committees to deal with contaminant related issues. The RCC developed the committees and held meetings in the three communities (Inuvik, Aklavik and Tuktoyaktuk). Communities were informed of the role and objectives of the NCP, and the communities informed the RCC of their concerns. Aklavik requested a workshop on methylmercury in muktuk and more general information on contaminants.

4. Some workshops/meetings in whic the IRC RCC participated included: Mercury Workshop (Ottawa); the NWT ECC; the NCP Results Workshop (Calgary); the Eastern Arctic Workshop (Iqaluit) in which the RCC helped Inuvialuit delegates prepare future proposals submissions for the NCP; the Fisheries Joint Management Committee (FJMC) annual community tour to two coastal communities (Paulatuk and Holman) where the RCC met with the members of the HTCs to discuss contaminants issues, provided an update on RCC activities, and suggested to the HTCs to develop an interim plan on how to deal with contaminants in their region; a three-day Frontline Training course sponsored by the Métis Nation - NWT, in Aklavik; and numerous meetings held in the Aklavik region concerning ITC's Cancer Registry Project.

RESULTS AND DISCUSSION

The success of the Regional ContaminantS Coordinator in the Inuvialuit region proved to be a powerful inspiration during the Eastern Arctic Workshop. IRC RCC was key in sparking the interest and awareness to the other Inuit regions. The comments, concerns and advice that came from the RCC helped to shape the path and direction not only for Nunavut, Labrador and Nunavik but for ITC as well.

Project Completion Date: The project is ongoing. Billy Archie has stepped down from his IRC RCC role and was replaced by Lena Selamio who will be taking on these duties for the 1999/2000 year.

DEVELOPMENT OF A COMMUNICATION PACKAGE ON CANCER AND INUIT IN RELATION TO NORTHERN CONTAMINANTS AND THE NWT CANCER REGISTRY

Project Leader: Eric Loring and Scot Nickels, Inuit Tapirisat Canada (ITC)

Project Team: Stephanie Sibbeston and Allison Armstrong, Dene Nation; William Kemp, Caroline Kemp and Cesare Tatarelli, Strata360; Olivier Receveur, Centre for Indigenous Peoples' Nutrition and Environment (CINE); Billy Archie, Inuvialuit Regional Corporation (IRC); Dr. André Corriveau, GNWT Health; Alan Penn, Grand Council of the Cree; MM Drew, Director of Nursing, Montreal General Hospital; Mimi Breton, Department of Fisheries and Oceans (DFO)

OBJECTIVES

The overall objective is to develop a CD-ROM presentation with up-to-date information on the key issues and concerns about cancer that have been identified by Inuit, in order to deliver a message of hope, not hopelessness, about cancer into Inuit communities.

Specifically, this project is designed to:

1. Review current information about cancer, including the types and possible causes among Inuit, and to stress known and possible relationships between contaminants and cancer in Inuit.
2. Identify Inuit concerns and perceptions about cancer and its causes, treatments cures and prevention.
3. Review and evaluate the statistics available from the NWT Cancer Registry and to expand these with the addition of statistics from Labrador and Nunavik.
4. Review current information on the causes, treatment and prevention of cancer in relation to the special needs, programs and facilities of Inuit.
5. Evaluate and summarize this information in plain language with supporting graphics, and to prepare a comprehensive communication package in the form of an interactive CD-ROM.

DESCRIPTION

Over the last decade, cancer has become an increasing concern in Inuit communities. Specifically, questions have been raised by Inuit communities, organizations and individuals about the actual or perceived increased rates of cancer and about the possible link between cancer and the presence of persistent organic pollutants (POPs) and other contaminants in the northern environment. ITC, in partnership with the Northern Contaminants Program, recognized that the concerns voiced by Inuit in all regions must be responded to through the development of a communication package.

As part of the response to Inuit concerns, the NWT Cancer Registry was established. It has become apparent, however, that there is an urgent need to provide the regions and the communities with a meaningful level of interpretation of this Registry and, equally important, to place these statistics in the broader context of cancer, its causes, prevention and treatments.

The importance of initiating the Cancer Registry Project was reiterated at the ITC environmental workshop held in Inuvik in April 1998 and at the Eastern Arctic Contaminants Workshop held in Iqaluit in December 1998. At these workshops, the need to develop a comprehensive communication package was reiterated. Equally important, however, discussions at these workshops and other meetings raised the problem of relying on workshops and meetings as a primary means of communicating information of this type.

Concerns were voiced about the fact that information presented at workshops often does not reach a large audience nor is it certain that all of the appropriate target audiences are being represented. In addition, workshops are single events that must be followed up with reports or other descriptive documents.

As a result of these discussions, the advantages of using CD-ROM technology as an alternative to workshops, or more appropriately as an extension of workshops and other more traditional methods of communication was examined, and a consensus was reached to develop a CD-ROM based communication package. This package will enable the information to reach a larger audience because it can be used in several different fora on several different occasions. The CD-ROM will provide, through the use of information layers, more information to better meet the expectations and needs of the target audiences than can be met within a printed communication package, or through meetings.

The approach stresses the importance of identifying and explaining different types of relevant information about cancer in the north. To accomplish the project objectives, the CD-ROM will contain much more information than is available simply from the Cancer Registry itself. The intent is to go beyond the Registry and to place the statistics in a far more meaningful and culturally relevant context.

As a communication package, the topics, data, questions, answers, options and alternatives presented in the CD-ROM must be compatible with Inuit culture and the realities of health programs and services offered to Inuit. In so doing, the information and approach provided by this project must be sensitive to the fears that are so often created by cancer as an illness. This CD-ROM will, therefore, deliver a message of hope, not hopelessness, about cancer.

ACTIVITIES IN 1998/99

The first stage of work began with an information workshop in Ottawa on December 15, 1998 at the ITC office. Dr. Corriveau presented to ITC, CINE and Inuit regional representatives, an overview of cancer statistics in the NWT, with special emphasis on Inuit communities. This workshop was recorded on video tape by Strata 360 for subsequent incorporation into the CD-ROM.

Following the workshop, a full set of the statistics and graphs of NWT cancer statistics was obtained. This information has been reinterpreted it terms of its graphic presentation and in terms of the approach needed to explain the implication of these statistics. The statistics will then be explained in length in terms of what their meaning holds for Inuit.

Individual cancer survivors have been identified and plans have been established to video their experience and message for inclusion in the CD-ROM. These survivors are primarily Inuit, but other individuals with links to Inuit are included. A total of four or five interviews are planned.

Schedule of Activities

December 1998
Organization of the Cancer Registry Workshop; participants gathered to discuss what the statistics mean to the Inuit of Canada; workshop was filmed.

January 5-31, 1999
Interpretation and development of new graphics for the NWT Cancer Registry; identification of additional statistical material and related information.

February 1 - March 31
Completion of first stage of work. All statistics for the regions were collected, identified and analysed.

June 1 - August 15
Collection, processing and production of all information required to meet the objectives of the CD-ROM.

August 16 - September 30
Preparation of storyboard and interface designs for presentation at the Partners Meeting and NCP Results Workshop.

October 1-30
Incorporation of feedback from the review process.

October 30
Launching of the beta version of the CD-ROM in the North through monitored sessions.

November 20
Final revisions and distribution of the CD-ROM to users.

DISCUSSION

Relevant information about cancer in general and in the North in particular is being identified, collected and prepared for integration into a CD-ROM based multimedia format. Contacts are being made with cancer authorities about the role they can play in explaining the cancer causes, treatments and therapies. These will most likely be videos that patients can refer to, as well as voice overrides when discussing particular cancer issues. Explanations about southern treatment centers will be included, which may include video segments of what the treatment centers look like, the nurses and doctors there, and a general description of the area. It is hoped that this will provide a sense of familiarity for the patient going to Montreal, Ottawa or Edmonton. Plans are now being established for how this information can best be represented within the available budget.

Individuals who will act as "reviewers" of the material and those who will represent the Inuit perspective and its inclusion in the CD-ROM have been identified and scripts are being prepared. A series of user-friendly interface screens have been developed to identify the content and navigation structure for the CD-ROM.

ITC chose to use CD-ROM technology for developing this communication package because CD-ROMs are certain to play an increasingly important role in northern communication and education. The cancer project provides an excellent opportunity to both demonstrate and evaluate its potential for this purpose. In addition, the utilization of CD-ROM technology provides an efficient cost option for meeting the project's information and communication objectives.

When the CD-ROM is completed it is hoped that a wide range of individuals will use it. The target audience is, of course, the Inuit of Canada, along with health care workers and health centers. This CD-ROM will also be an important educational tool that can be used in schools, meetings and workshops.

Expected Project Completion Date:
October 30, 1999

EASTERN NWT REGIONAL WORKSHOP ON CONTAMINANTS

Project Leaders: Carole Mills, Chairperson of the NWT Environmental Contaminants Committee (NWT ECC); Eric Loring, Inuit Tapirisat of Canada

Project Team: Members of the NWT ECC (representatives from Dene Nation, Métis Nation, Inuit Tapirisat of Canada, Inuvialuit Game Council, Nunavut Tunngavik Incorporated, Gwich'in Tribal Council, Sahtu Secretariat, Deh Cho First Nations, Dogrib Treaty 11, Akaitcho Territory Tribal Council, North Slave Métis, South Slave Métis, Department of Indian Affairs and Northern Development (DIAND), Environment Canada, Department of Fisheries and Oceans, Government of Northwest Territories (GNWT) Department of Resources, Wildlife and Economic Development (RWED), GNWT Health, Aurora Research Institute, Nunavut Research Institute)

OBJECTIVES

1. To communicate the goals, objectives and priorities of the Northern Contaminants Program (NCP) Phase II as well as relay the findings of the NCP Phase I.
2. To identify the issues and concerns of communities in the eastern NWT with regards to contaminants in the environment.
3. To review the success of past communication efforts to inform individuals and communities about contaminants in the environment.
4. To introduce the NWT Environmental Contaminants Committee to Northerners.
5. To assist individuals and communities in making informed decisions about their use of country foods.

DESCRIPTION

A main effort of the Northern Contaminants Program (NCP) has been the communication of contaminants-related concepts, results from numerous studies undertaken and aspects of the Program itself, to people of the North. A method favoured by the NCP for transmitting this information has been workshops. There have been a number of successful regional and special occasion workshops held to discuss the concepts and issues of contaminants in the North. The focus has usually been on a specific region and its concerns, and the workshops have been conducted mainly in the western Arctic. Also, topic-specific workshops such as the Arctic Archipelago Workshop and the Mercury Workshop have been held to discuss the possibilities of integrated studies to address specific problems.

As the focus of the NCP shifted towards the eastern Arctic, it was realized that a larger multi- regional workshop with representatives from communities in the eastern NWT needed to be held in order to provide the opportunity to discuss common concerns, talk about research that was going on outside their specific area and share solutions. It would also provide an opportunity to gauge the level of contaminants-related knowledge, which in turn, would help to guide any future communications work.

ACTIVITIES IN 1998/1999

The NWT Environmental Contaminants Committee (NWTECC) hosted the Eastern Arctic Contaminants Workshop in Iqaluit, December 3-5, 1998. In preparation for this workshop, numerous organizational meetings were held by the organizing committee, which was comprised of a representative from the Inuit Tapirisat of Canada, Inuvialuit Game Council, Nunavut Tunngavik Corporation, Nunavut Research Institute and DIAND Contaminants Division.

RESULTS

A total of 65 people participated in the three-day workshop. The agenda for the workshop is found in Appendix A .

DISCUSSION / CONCLUSION

Participants shared a common concern about contaminants in the environment. They felt that social and scientific researchers need to improve their efforts to communicate by making sure that the information is passed back to the communities from which it was collected as well as by making the information more easily accessible from both a geographical and an ease-of-understanding perspective. They also felt that there was a lack of involvement of Northerners in the research. It was felt that more attention should be paid to the local environmental knowledge held by the people in the communities to help answer the questions.

While this workshop was successful in providing an initial introduction to contaminants to a large number of community representatives, its greatest benefits will be in documenting the concerns people in the eastern Arctic have about contaminants in the environment and the way contaminants research or information has been and should be communicated.

Expected Project Completion Date: A summary of the workshop is being prepared and will be distributed to the participants as well as anyone interested.

APPENDIX A

EASTERN ARCTIC CONTAMINANTS WORKSHOP
December 3-5, 1998, Cadet Hall, Iqaluit NWT
Agenda

THURSDAY, DECEMBER 3 - MORNING

8:00 - 8:45	Registration
8:45 - 8:50	Opening Prayer - Gamilee Kilukisiak
8:50 - 9:00	Welcome - Okalik Eegeesiak
9:30 - 10:00	Introductions
10:00 - 10:15	Break
10:15 - 10:45	Goals \ Objectives \ Outline of Workshop - Eric Loring
10:45 - 11:45	Primer on Contaminants - Carole Mills

THURSDAY, DECEMBER 3 - AFTERNOON

1:00 - 2:00	Traditional Knowledge and Science - Zack Novalinga
2:00 - 4:30	Roundtable Discussion of Concerns - What are your community concerns regarding contaminants - Do you have an environment committee? - What contaminant projects is your community involved in?

FRIDAY, DECEMBER 4 - MORNING

8:30 - 10:00	Ecosystem Information - Contaminants in the Marine Environment - Derek Muir - Contaminants in the Terrestrial Environment - Brett Elkin
10:00 - 10:15	Break
10:15 - 11:30	Discussion Groups
11:30 - 12:00	Plenary Session

FRIDAY, DECEMBER 4 - AFTERNOON

1:00 - 5:30	Abnormalities in Wildlife - World Wildlife Fund

SATURDAY, DECEMBER 5, MORNING

8:30 - 10:00	Human Information - Human Health and Contaminants - Peter Barrs - Diet and Socio-Cultural Benefits - Olivier Receveur
10:00 - 10:15	Break
10:15 - 11:30	Discussion Groups
11:30 - 12:00	Plenary Session

SATURDAY, DECEMBER 5, AFTERNOON

1:15 - 4:00	Information and Resources \ Question Period
4:00 - 4:15	Closing - Eric Loring and Carole Mills
7:00	Feast

CONTAMINANTS FOUND ME: A SCIENCE CURRICULUM FOR YUKONERS

Project Leader: Mark Palmer, Chair, Yukon Contaminants Committee

Project Team: Jeanne Burke, Curriculum Developer, and Bob VanDijken and Nick de Graff, Technical Assistants, Yukon Department of Education; Yukon Contaminants Committee

OBJECTIVES

The purpose of this project is to build on the *Contaminants in Northern Canada* (1995) science curriculum developed by the Métis Nation Contaminants Education Program. The intent is to create a curriculum project with Yukon perspectives. This means:

To develop topics specific to Yukon:

1. To match the curriculum to the Yukon Department of Education's science curriculum;
2. To involve Yukon teachers and students in developing curriculum activities for Yukon classrooms; and
3. To focus concepts in the context of Yukon First Nations and local people, wherever possible.

DESCRIPTION

Following the 1994 Northern Contaminants Program results workshop, the Yukon Contaminants Committee mandated that education and communication were to be important components of its program. In 1995 and 1996, the Métis Nation – NWT Northern Contaminants Education Program produced a three-volume science education curriculum package addressing the following topics: Environmental Concerns, Nuclear Energy, Northern Food Chains and Webs, and Pulp and Paper (Métis Nation - NWT, 1995a, 1995b, 1996). Concepts explored in this particular science curriculum are relevant to all of northern Canada but are illustrated within frameworks that are particular to the Northwest Territories and Nunavut. Yukon teachers have a preference to illustrate concepts in frameworks specific to the Yukon, and wherever possible, to present information with relevance to Yukon First Nations.

Material presented in the Métis Nation – NWT Northern Contaminants Education Program curriculum match the junior curriculum strands mandated in the Northwest Territories. Though it may seem easy to lift materials from one curriculum to another, this is usually not the situation. Schools are structured differently between the two regions, and learning objectives vary. This can affect the presentation, distribution and use of material.

Materials developed in the Yukon in collaboration with Yukon teachers and students are supported by the Yukon Department of Education and Yukon Teacher's Association. The curriculum development process then, in itself, becomes an educational process. Students and teachers learn about concepts highlighted in the curriculum while experiencing the curriculum and curriculum development. In essence, curriculum implementation commenced in the early phases of curriculum development.

ACTIVITIES

This project commenced in October 1997 and will conclude in March 2000.

October 1997 - March 1998
Background research was conducted and possible topics to be used as frameworks for learning concepts were selected. The following agencies were contacted for cooperation and support for curriculum development in the classroom: Yukon Department of Education; Yukon Teacher's Association; Yukon Native Teacher Education Program (Yukon College); Yukon Environmental Educator's Association; and administrators or teachers in all Whitehorse area schools.

April 1998 - March 1999
Ideas were taken into a number of classrooms. Visits to the classroom took on the shape of single presentations, field trips and camp-outs, or successive visits. Some classroom visits were conducted with the cooperation of scientists or specialists conducting research on specific topics related to contaminants. The majority of

these visits happened during the spring and fall of 1998.

Curriculum materials began to take form in late 1998. Ideas for a series of three posters introducing *Monty the Moose* were developed with illustrators (Aasman Design) and approximately 200 Yukon students. Illustrations to be used as graphics for the written text were developed by Tanya Handley (Illustrator) and tested as overhead transparencies in numerous classrooms. Ideas for the video *Contaminants Found Me* were developed into a storyboard and script with Nick de Graff and students of the M.A.D. (Music, Art & Drama) 9/10 program. The music for *Contaminants Found Me* was cut to CD under the direction of musician Andrea McColeman and the M.A.D. 9/10 students. A demo video of *Contaminants Found Me* was prepared by AV Action Yukon and a second video, titled *Acid Rock*, was drawn from rough footage by Treeline Productions. All artistic productions have been developed with students, and tested in the classroom as tools for the presentation of scientific concepts.

Late in the fall of 1998 the curriculum developers commenced classroom visits to community schools. They also began working with Elders, Native Language Instructors, and the Department of Education First Nations Consultants in an effort to connect the curriculum to First Nations world views.

RESULTS

More than 50 teachers and their students in 24 out of 29 Yukon schools participated in the curriculum development process. Native Language Instructors, Yukon's Department of Education First Nations Consultants and Yukon Native Teacher Education Program (Yukon College) were also involved in some aspect of this project.

Classroom visits and poster production concluded in the late spring of 1999. A number of materials, some of which are in various stages of preparation for final presentation, will reach Yukon classrooms in the fall of 1999. These will include: a three-poster series, *Monty the Moose*; a CD, *Contaminants Found Me*; two videos, *Contaminants Found Me* and *Acid Rock*; chemistry kits (grade 7); and three curriculum/activity guides, *Contaminants Found Me: a curriculum for Yukoners*, (book 1: grades 3 - 6, resource guide), (book 2: grade 7, resource guide) and (book 3: grades 8 and 9, resource guide).

Requests for classroom visits are continuous and will be carried out until the end of the project.

DISCUSSION / CONCLUSIONS

This curriculum development has been an interactive process involving many Yukon teachers, students, First Nations educators, scientists and specialists. Concepts developed in the curriculum package are a result of numerous classroom trials. These trials provided direction in determining the best possible approach in educating Yukon students and teachers about contaminants. As classroom sessions evolved, a sense of teacher professional development took form. Teachers learned about contaminants in the Yukon and about the materials soon to be available, as well as gaining a perspective in connecting society, environment and science in the classroom.

Although the materials have been introduced and groundwork has begun in many Yukon classrooms, the curriculum development/implementation process only marks a beginning. Ideally, materials should be followed and revised on an ongoing basis. This however, is beyond the objective and scope of this particular project.

Expected Project Completion Date: March 31, 2000.

REFERENCES

Métis Nation – NWT. 1995a. Contaminants in Northern Canada. Lesson Plans for Grade 7 Science 1. Environmental Concerns 2. Nuclear Energy.

Métis Nation – NWT. 1995b. Contaminants in Northern Canada. Lesson Plans for Grade 8 Science 1. Northern Food Chains and Webs 2. Pulp and Paper.

Métis Nation – NWT. 1996. Contaminants in Northern Canada. Information for Science Teachers Grades 7, 8 and 9.

ELDERS/SCIENTISTS RETREAT III: "STRENGTHENING THE TIES IN DENENDEH III"

Project Leader: Stephanie Sibbeston, Dene Nation Lands and Environment Department

Project Team: Miriam Tyson, Métis Nation-NWT; Eric Davey and Timothy Cook, Dene Nation Lands and Environment Department

OBJECTIVES

1. To continue to build on the progress made at the first two Elders/Scientists retreats.
2. To put together a framework for a publication called "Traditional Knowledge for Dummies", aimed at helping scientists conducting research in the North.

DESCRIPTION

While traditional knowledge is rapidly gaining respect in the scientific and political community, the next step is to form partnerships between scientists and traditional knowledge holders. The Dene Nation recognized the need first to build trust and respect between the two groups. This was an objective at all three Elders/Scientists retreats. At the third retreat, elders and scientists explored ways to work together and made recommendations for incorporating traditional knowledge in Northern research.

ACTIVITIES IN 1998/99

The 3rd annual Elders/Scientists retreat was held at Blachford Lake Lodge, an informal setting close to nature where the participants could express their questions and concerns freely and listen to each other with open minds. It was attended by nine Dene Elders, four Dene youth and six scientists.

Elders, scientists and youth accomplished the goals of the retreat through plenary and group discussion, walks on the land where Elders' traditional knowledge of plants and social and ecological history were evident, and through enjoying together a traditional drum dance and Dene hand games.

Some of the Elders and scientists at the third retreat had attended one or both of the previous workshops. They brought to the retreat a willingness to work together and to build upon the progress of the last two retreats. The Elders repeatedly expressed thanks for the opportunity to speak with the scientists. Scientists wanted to find tangible ways to incorporate traditional knowledge into their research.

> *"When we get together and talk like this, it's not for today, but for the future also... We are not here for ourselves but for everyone else.."*
>
> Paul Wright, Elder, Tulita

> *"The scientists are here to help as much as they can. Elders have ancient stories that the scientists can use... The youth are not here on earth for nothing, they are here to listen and learn, so that the knowledge of old ways can be passed on to the future."*
>
> Judy Colin, Youth, Fort MacPherson

> "These workshops make scientists aware of traditional knowledge... this is a start. We've got to get more people coming here before they have their whole program designed so that they can consider these things."
>
> Jay Van Oostdam, Scientist, Health Canada

RETREAT DISCUSSIONS

1. Elders' Concerns

The Elders' lives are closely connected to the land. Their view of the environment is holistic: the people, the plants, the animals, the water are all interconnected. Something that touches one part will affect the whole. One cannot talk about contaminants without also talking about mines and dump sites and caribou. So, while the focus of the workshop was to find tangible ways to forge partnerships between science and traditional knowledge, the scientists also learned a great deal about the Elders' concerns with respect to the environment. Some of these concerns echo what was already said at previous workshops. All point to the importance of including local people in all aspects of research in the North, especially in guiding the direction of research.

The Global Ecosystem

The Elders' concerns are not limited to their own region. It is consistent with their holistic view that they should also be concerned with other parts of the Earth's ecosystem. Global warming, hydroelectric dams and acid rain were all mentioned at the retreat.

Local Pollution

There is a great deal of concern about local mines, that there is not enough consultation with Elders and as a result costly accidents may occur. Issues strongly associated with local mines were the safety of the water and the changing caribou migrations.

> *"The mining has a big influence with the changes of caribou migration."*
>
> J.B. Rabesca, Elder, Lutsel K'e

Traditional Food

Elders are concerned that, whether from long-range transport of pollution or local point source, the food will not be safe to eat, or the water safe to drink. Traditional food is a source of cultural identity and health for many Dene people. Contamination of their environment is something they experience directly, unlike people in many cities who grow up drinking from a tap, and not from a river.

> *"All of the different forms of water are important, water gives us life, and that is what I have grown up on."*
>
> Paul Wright, Elder, Tulita

> *"The land is like our fridge to us."*
>
> Jim Perriot, Elder, Fort Good Hope

> *"I have heard so much about contaminants here, I think I am going to eat sticks."*
>
> Paul Wright, Elder, Tulita (jokingly)

Concerns in Common with Southerners

The Elders had many concerns that are shared with households in the South. Mary Teya (Elder, Fort MacPherson) wondered about the effect of modern technology such as television on families and communities. She wanted to know more about diabetes, heart disease and cancer, which seem to be on the rise. Elizabeth Colin (Elder, Fort MacPherson) asked about proper disposal of plastics, spray cans and cleaning materials. The Elders worry about the future of the young people.

> *"We need to get together at a community level, interact with one another, Elder to youth and vice-versa."*
>
> Mary Teya, Elder, Fort MacPherson

Treatment of Wildlife

The Elders expressed strong feelings about the treatment of animals. Since the animals give life they are respected. The tagging and collaring of animals bothers them because they have seen animals that were harmed by this. Problems with sport fishing are that it does hurt the fish, which is the food of the local people; sport fishers and hunters are playing with their food.

> *"The traditional knowledge says you can't tag a fish, but science wants to tag the fish to find out where it came from… I'm a youth, I'm sitting back and trying to figure it out!"*
>
> Matthew Betsidea, Youth, Deline

Adaptation to Changes

The Elders have noticed many changes over their lives. These changes concern them, but there is recognition that some changes are inevitable, and we must find a way to take care of the environment in the modern world.

> "In the old days we took very good care of our land and the land took good care of us. Compared to a long time ago, I've noticed a lot of changes with people and our land. I don't know anyone now that can reverse what is happening to us and our land… When there is some type of damage on the land it is because they are producing something else from it, and we have to consider this and talk and come to some sort of decision."
>
> Paul Wright, Elder, Tulita

2. Building A Framework for Partnership:

Every meeting between Elders and scientists is a new chance to build trust and respect for each other. At this retreat it was clear from the outset that the scientists wanted to include traditional knowledge in their research but were unsure of the proper procedure. Conversely, the Elders recognized that modern technology has much to offer, but a history of exploitation and broken promises has left them with little trust for research.

Building on the relationships formed at the last two retreats, scientists and Elders were given the opportunity to ask questions of each other. It was clear from some of the questions (*"Who is an Elder? Who is a Scientist?"*) that there is still a need to understand where each is coming from. The ensuing discussions also illustrated the need for patience in communication across cultural, linguistic and ideological barriers.

RESULTS

Specific recommendations were made during the retreat for a publication about traditional knowledge for scientists conducting research in the North, and for future Elders/Scientists workshops.

Recommendations for a "Traditional Knowledge for Dummies" publication:

- Definition of traditional knowledge
- Why it is important to use traditional knowledge
- How to communicate with Elders and local people
- Examples to show the geographical and historical extent of Elders' knowledge
- How to involve Elders and local people in research
- How to show respect
- Common values, positive examples
- Examples where traditional knowledge has contributed to research
- Intellectual property rights
- How to store and keep traditional knowledge and have it available

- References to past traditional knowledge studies

Recommendations for future Elders/Scientists workshops:

- The Elders had many specific concerns with respect to specific issues. Bring people who can speak to local point source pollution issues, chronic disease concerns, specific studies in the Arctic. More scientists, more local people! (Norma Kassi, Council of Yukon First Nations)
- Make the retreat longer. The Elders emphasized the need to spend time on the land.
- Scientists must be patient and listen carefully. *"If Elders are forced to only talk about one subject, they will not be willing to share anything. This is a two way process, and this needs to be recognized by the scientific community. It is not only relevant to these types of retreats, but to the researchers who have to work in the communities"* (Stephanie Sibbeston, Dene Nation).
- Communicate results from the workshop to help other scientists communicate with Elders and convince them, also, that considering the traditional knowledge of local people is not only a requirement of research in the North but is valid and worthwhile.

Further general recommendations included

- Traditional knowledge, its extent and its importance, should be explained to scientists;
- Scientists need to know how to communicate with Elders and communities and how to involve them in research;
- The concerns of Elders should be steering the direction of research, and there must be two-way communication;
- There should be more discussion with Elders to respond to the variety of their concerns; and
- The lessons from the workshop should be made available for scientists who were unable to attend.

The official final report provides a more detailed summary of the retreat (Dene Nation 1999).

CONCLUSIONS

Traditional knowledge of the environment can fill some gaps in scientific ecological information. For example, local hunters and trappers are the most qualified to monitor changes in the local environment and fauna. Since research in the North is relatively recent, traditional knowledge also provides the only record of historical ecology. It can also add the human and cultural values that are missing in science.

It is possible to bridge the differences between traditional knowledge and science. One way is for communities to take charge of documenting their knowledge. For example, Inuit and Cree have collected their traditional ecological knowledge of the Hudson Bay bioregion (Novalinga *et al.* 1997) This type of project makes traditional knowledge more accessible and the source easy to credit.

Documentation is useful, but traditional knowledge, like science, is dynamic. As long as there are people living on the land, there will be traditional knowledge which understands that land intimately and in a way that science does not. Therefore it will always be important for scientists and local people to have open channels of communication.

The presence of youth at the camp added a note of hope for the future:

> *"Since I've been here, I've noticed that scientists have learned a lot from Elders about traditional knowledge, our culture and respect for nature. I've learned how we can work together as individuals, as a group and as a team, and forgive our past, because the next generation will be taking over and we must be set to make things right, and better."*
>
> Matthew Betsidea, Youth, Deline

People who live on the land can benefit from science and technology, and scientists can learn from traditional knowledge.

ACKNOWLEDGEMENTS

The Dene Nation wishes to thank the Elders, Scientists, youth and interpreters for their participation in the retreat. In addition we would like to thank the following individuals for their hard work and active participation in this retreat:

Retreat Planning Committee:
Stephanie Sibbeston, Eric Davey and Timothy Cook, Dene Nation

Retreat Facilitators:
Norma Kassi, Council of Yukon First Nations; Carole Mills, Contaminants Division, DIAND; Stephanie Sibbeston, Dene Nation

Interpreters:
Lucy Ann Yakeleya, Yellowknife; Bertha Catholique, Yellowknife

Sincere thanks and appreciation to the following organizations that, with their support and funding, made this retreat possible:
The Northern Contaminants Program (NCP); Human Resources, Development Canada; Blachford Lake Lodge; Dennis Allen Productions

REFERENCES

Dene Nation. 1999. Elders/Scientists Retreat III: Strengthening the Ties in Denendeh III. September 18-21, 1998, Blachford Lake, NT. Summary Report. 27 pp.

Novalinga, Z. *et al.* 1997. *Voices from the Bay*. Canadian Arctic Resources Committee.

NWT CANCER COMMUNICATION PACKAGE

Project Leader: Stephanie Sibbeston, Dene Nation Lands and Environment Department; Dr. André Corriveau, Department of Health and Social Services, Government of the Northwest Territories (GNWT)

Project Team: Dene National Office; Métis Nation-NWT; GNWT Health; Centre for Indigenous Peoples' Nutrition and Environment (CINE); Gwich'in Tribal Council; Sahtu Tribal Council; Deh Cho First Nation; Akaitcho Territory; South Slave Métis Alliance; North Slave Métis Alliance

OBJECTIVES

1. To retrieve the preliminary NWT Cancer Registry Statistics and present them to the Dene/Métis communities in a Western NWT Workshop.
2. To receive feedback and input from the workshop participants in order to develop a communication package that can be used for communities in the NWT.

DESCRIPTION

Concern regarding cancer has risen over the last decade among the Dene and Métis people. There have been questions from the communities as to whether perceived increasing rates of cancer are due to the contaminants influx that the North has been experiencing. Before looking at the relationship between cancer and contaminants, regions and communities need to be provided with information and a meaningful level of interpretation of the NWT Cancer Registry.

The GNWT Director of Population Health agreed with Health Canada and the Northern Contaminants Program (NCP) to release data on cancer rates in the Northwest Territories. GNWT Health worked with Aboriginal organizations to deliver this information. Both GNWT Health and the Aboriginal organizations recognized that the people of the North were best suited to bring this information to the communities. The development of the communication package containing this information took a holistic and thoughtful approach. Everyone involved wanted to bring hope into the communities, not a sense of hopelessness.

The Northern Aboriginal communities agreed to have the Dene Nation work, as coordinator, to prepare workshop materials for delivery to communities. Some of the issues to be covered include: traditional knowledge of cancer; communities' perception of cancer and its causes; dietary changes that have taken place in the last decade; and known causes of cancer.

ACTIVITIES 1998/99

The Dene Nation Lands and Environment Department received funding from the NCP to develop a culturally relevant communication package on cancer in the Western NWT for the people of the North. Cancer has always been a concern to the Dene and Métis of the NWT, and it is a common perception that contaminants are the primary cause of the increased cases of cancer in the NWT.

A focus group, composed of Dene and Métis representatives, GNWT Health and the Centre for Indigenous Peoples' Nutrition and Environment (CINE), was established to develop the communication package. The Aboriginal component of the focus group had representatives from the Gwich'in Tribal Council, Sahtu Tribal Council, Deh Cho First Nation, Akaitcho Territory, South Slave Métis Alliance, North Slave Métis Alliance, Métis Nation and the Dene National Office. Although the Dogrib Treaty #11 opted not to be involved in the project, we continued to send information to their Director of Health and Social Services and invited them to participate at any time. Everyone involved in this project has been touched by cancer through work and/or personal experience.

The bulk of the information in the cancer communication package was collected from various sources and adapted for the North. Inside the package, each topic is divided into three sections: overheads, speaker notes, and a hard copy of an accompanying pamphlet. The speaker notes are meant to provide background information for each overhead. The pamphlets contain some of the same information, and provide workshop participants with material that they can take with them. The pamphlets also contain additional information about contacts, resources and references.

When using the information contained within the package, it is very important that:

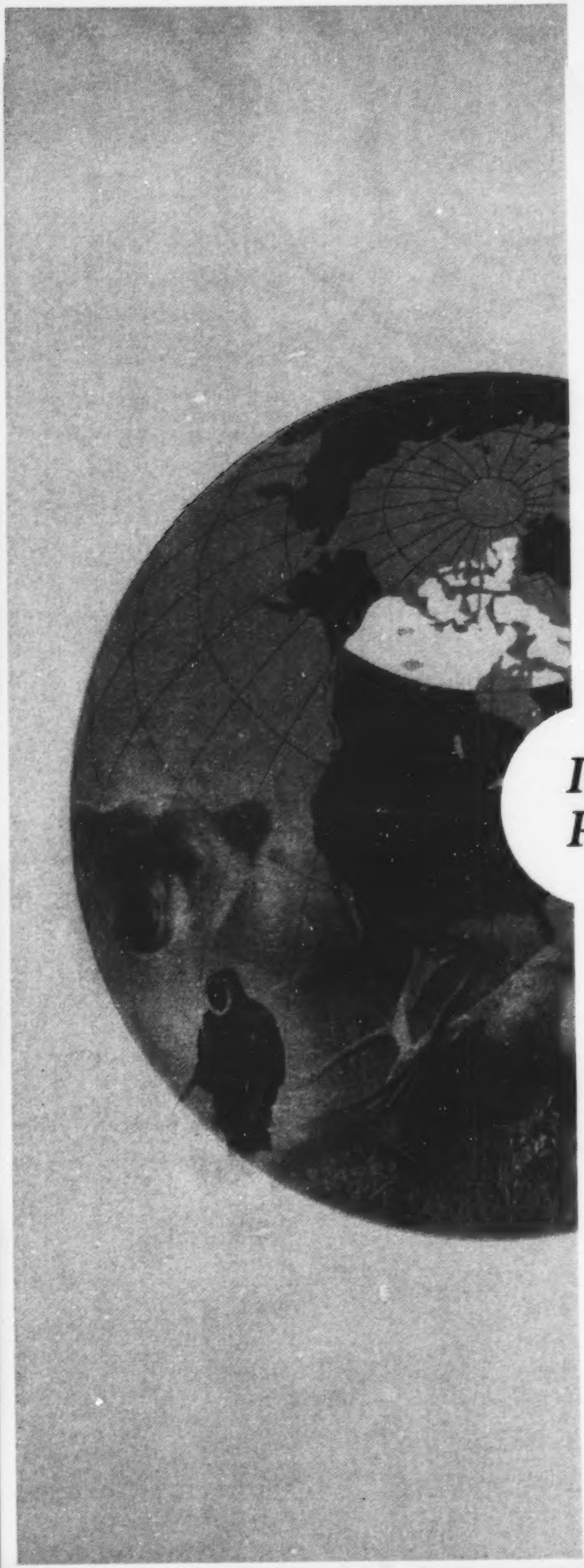
(a) the presenter contact either GNWT Population and Health and/or the Lands and Environment Department, Dene National Office, to ensure that the information in the package is current;
(b) the presenter has been oriented with the package by the Dene Nation or GNWT Health;
(c) the workshop be coordinated with care givers so follow-up can be arranged;
(d) a public health professional is present to answer questions about cancer; and
(e) a cancer survivor be present at the workshop to show that people can and do survive cancer.

The information package does not have to be used in its entirety. A good way to deliver a workshop based on this material is to let the participants know the scope of information that is available, and then ask the participants what it is they would like to cover. If the workshop group is large. it may be best to break into smaller circles of people, as many people feel intimidated speaking in larger groups. Cancer can be quite a heavy topic; people may need an opportunity to share their stories or to have some quiet time, go for a walk, or have some comic relief. It is important to be flexible.

For more information on the Cancer Registry Information Package please contact either:

Dene Nation
Lands and Environment Department
P.O. Box 2338
Yellowknife, NT X1A 2P7
Tel: (867) 873-4081
Fax: (867) 920-2254

Dr. André Corriveau
Chief Medical Health Officer
Department of Health and Social Services
6th Floor Centre Square Tower
Yellowknife, NT
Tel: (867) 873-3132
Fax: (867) 873-0442



International Policy and Program Coordination

RESPONSE STRATEGY FOR RISK:BENEFIT EVALUATION OF ARCTIC TRADITIONAL FOOD SYSTEMS

Project Leader: Harriet V. Kuhnlein, Laurie Chan, Olivier Receveur and Staff, Centre for Indigenous Peoples' Nutrition and Environment (CINE), McGill University

Project Team: CINE Governing Board (Assembly of First Nations, Council of Yukon First Nations (CYFN), Dene Nation, Inuit Tapirisat of Canada (ITC), Inuit Circumpolar Conference (ICC), Métis Nation - NWT, Mohawk Council of Kahnawake), and CINE staff

OBJECTIVES

1. To build capacity in communities to address the issues raised by the presence of contaminants in traditional food.
2. To provide consistent technical support for communities on topics related to the CINE mission and goals on the sciences of nutrition and environment of Indigenous Peoples.

DESCRIPTION

Since 1992, the Centre for Indigenous Peoples' Nutrition and Environment (CINE) has been promoted as a resource for Aboriginal communities to address concerns about their nutrition and environment. Activities requested by communities have been extensive: attending community and regional meetings; production of videos and newsletters; literature reviews; liaison with experts for problem solving; conducting preliminary studies; assisting with preparation of research proposals; interpreting existing data; and conducting risk and benefit assessments.

CINE's response strategy for community requests on research or education issues has developed a good reputation and has been extremely successful and popular with communities. This project served as interim support until the CINE strategic plan was completed and begun to be implemented.

ACTIVITIES IN 1998/99

During 1998/99, CINE Board members fostered many initiatives and collaborations with the support staff and offices of CINE.

Research was conducted on:

- the extent of radioactivity in food samples from Deline;
- arsenic in berries near Yellowknife;
- organochlorines in beaver and muskrat in Fort Resolution;
- organochlorines in food samples from Baker Lake;
- radionuclides in food and diets in Lutsel K'e; and
- nutrients in moose broth for three communities of the Conseil de la Nation Atikamekw

Additionally, CINE contributed to the ITC initiative on qualitative research on food use.

Proposals were developed for:

- the Cape Mudge, Quadra Island people to understand organochlorines and metals in traditional food, particularly seal;
- Cree First Nations and New Brunswick First Nations to help understand contaminants in traditional food;
- the evaluation of traditional food systems of indigenous peoples in Russia and for the Millenium Fund with ICC; and
- results communication with CYFN.

Information was shared with:

- the Innu on bear and food safety;
- Hopedale, Labrador on food shelf life and food safety;
- 28 First Nations communities in Northwest Ontario on audiovisual materials available in health and nutrition education;
- the Whispering Pines/Clinton Indian Band on traditional food, diabetes, and cancer; and
- the Dene Nation on the extent of use of snow goose by northern communities

Resources and information on traditional food and nutrition was also shared with a variety of individuals and organizations requesting this information.

Other activities included:

- participating in the National Environmental Contaminants Program for First Nations conference at the request of the Assembly of First Nations and the Kahnawake Schools Diabetes Prevention Program;
- attending the Atikamekw Food Guide celebration in Manawan;

- requesting for speaker on diabetes for consultation workshop in Cambridge Bay;
- presenting at the International Day of the World's Indigenous Peoples in Hull;
- providing advice to the Kitchenuhumaykoosib Inninuwid (Big Trout Lake, Ontario) First Nation on an on-going environmental contaminants health study;
- responding to several questions on graduate training and distance education based from CINE;
- consulting the advisory group for the Aboriginal Health Institute on two occassions;
- discussing plans to evaluate the traditional Inuit food system of Greenland;
- exchanging laboratory protocols and advice with the Makkivik Research Centre in Kuujjuaq;
- developing a cancer statistics database in the NWT for use by ITC, Dene Nation, and communities; and
- developing a distance course for prenatal nutrition workers in the NWT.

In addition to the above activities, CINE continued to develop the methods of analysis for dietary data and food samples collected during the projects conducted with communities of the Dene Nation, Métis Nation - NWT, Yukon First Nations, and Inuit. Several presentations of research results were made to diverse audiences in national and international settings. Other activities include the hosting of the CINE Governing Board meetings and participation in the Northern Contaminants Program meetings.

DISCUSSION AND CONCLUSIONS

CINE staff continue to be a resource for communities associated with CINE Governing Board members. Activities related to research and education on topics of nutrition and environmental concerns are conducted in many different ways.

Expected Project Completion Date: Funding was provided for one year; however, activities are ongoing and increasing in size and number.

ICC CANADA AND TRANSBOUNDARY CONTAMINANTS

Project Leader: Terry Fenge, Inuit Circumpolar Conference (ICC) Canada, Ottawa, ON

Project Team: Project team members are outlined in each of the 'Activities' listed below

ACTIVITIES IN 1998/99

The 1998/99 fiscal year has seen extensive involvement by ICC Canada in transboundary contaminants issues using funding provided by the Northern Contaminants Programme (NCP). During this period, the President of ICC Canada became a full-time position, greatly increasing our ability to deal with pressing environmental policy issues. As well, ICC held its triennial assembly in Summer 1998. A long and detailed debate took place on transboundary contaminants following which ICC received direction to increase its involvement in this issue. The resolutions passed at the assembly are described below. Over the past year, many activities have been conducted in cooperation with Inuit Tapirisat of Canada (ITC) and other Aboriginal peoples represented on the NCP management committee.

Canadian Arctic Indigenous Peoples Against POPs

The Canadian Arctic Indigenous Peoples Against POPs (CAIPAP), formerly the Northern Aboriginal Peoples Co-ordinating Committee on POPs (NAPCC), has solidified as the vehicle to represent the interests of the Dene Nation, Métis Nation-NWT, ITC, Council of Yukon First Nations (CYFN), and ICC Canada in international negotiations dealing with persistent organic pollutants (POPs). While staff turnover in some of these organizations has presented difficulties of continuity, the coalition, co-ordinated by Stephanie Meakin, has engaged in conference calls and face-to-face meetings to work out collective positions. So far, all members of the coalition have agreed to shared positions. At the meeting of the Arctic Council in Anchorage, Alaska in May 1999, it was agreed to enlarge the coalition to include Sami, Russian Aboriginal peoples and Aleuts in both Russia and Alaska. As well, the coalition made presentations to the Sound Management of Chemicals working group of the North American Council on Environmental Co-operation (CEC). Indeed, it may be that additional work by the coalition on North American issues will be welcomed by the CEC. Ms. Meakin is submitting a separate report to the NCP and to the Department of the Environment on coalition activities.

Global POPs Negotiations

The coalition has proven its value over the past year by participating actively and productively in both International Negotiation Committee (INC) sessions in Montreal and Nairobi, using ICC's official observer status to the UN Economic and Social Council. Ms. Shiela Watt-Cloutier, President of ICC Canada, led the coalition delegations in Montreal and Nairobi, supported by T. Fenge, S. Meakin, and John Holman (Métis Nation - NWT). Arrangements were finalized early in the new year for Carole Mills, formerly of the Dene Nation and currently with the Department of Indian Affairs and Northern Development (DIAND) in Yellowknife, to join the Canadian delegation as a coalition representative. These arrangements have worked well.

ICC Canada contracted Nigel Bankes of the University of Calgary to prepare material on monitoring, inspection, verification and enforcement in existing international environmental treaties as models to consider in the forthcoming global POPs agreement. This material has been shared with the Canadian delegation. We believe firmly that these issues will be most important in ongoing negotiations. Our interventions in the global negotiations have been very well received. We continue to be critical of the positions taken by the Government of Canada in these negotiations, our aim being to strengthen the Canadian position and to have it more fully informed by the information generated by the NCP. Finally, we assisted the Government of Canada to transfer $60 000 to the United Nations Environment Programme (UNEP) for use in workshops to promote the case for the forthcoming global POPs treaty.

Global Environment Facility

As a result of our interventions in Montreal, we have been invited by the World Bank/Global Environment Facility (GEF) to submit a proposal to conduct a 3-5 year, $2 to 4 million research programme in Arctic Russia focussing on transboundary contaminants and country food. We received a GEF grant of $35 000 to bring people together in London last Summer and Moscow in April 1999 to draft the research programme. We expect to submit the proposal in early July, 1999 and to receive an answer in mid-October. Additional funding will be requested from Arctic nations, private foundations and the UN Foundation. If successful, this project would bring together the Arctic Monitoring and Assessment Programme (AMAP), Russian Association of Indigenous Peoples of the North (RAIPON), ICC Canada, Centre for Indigenous Peoples' Nutrition and Environment (CINE), and various agencies of the Government of the Russian Federation.

Arctic Council
We participated in numerous meetings of AMAP and PAME (Protection of the Arctic Marine Environment), both of which deal with the question of transboundary contaminants in the circumpolar Arctic. Our involvement is designed to help AMAP determine its activities in coming years, and to use its existing reports to advantage in international negotiations. In particular, we are urging AMAP forward to fulfill the public health aspects of its mandate. In addition, we have participated in meetings to help the federal government define its northern foreign policy and to prepare a project proposal on children and youth in the Arctic for consideration by the Council. We are using the foreign policy exercise to press for additional money to conduct contaminants-related research. The proposed children and youth project deals, in part, with the long-term effect of contaminants on young people.

Centre for Indigenous Peoples' Nutrition and Environment
Terry Fenge represents ICC Canada on the Board of CINE. CINE has recently completed a strategic planning exercise and, we hope, is back on the road to institutional health. Not only have we participated in its internal planning, but we drafted the millennium celebration application for over $300 000, submitted to the federal government late last year. This proposal was submitted with the written support of all organizations represented on the board of CINE. ICC Canada is currently drafting a proposal for foundations to fund an Executive Manager for CINE. If this position is funded, it will go a long way to ensuring the continuity of CINE.

Northern Contaminants Programme
ICC Canada has participated in the preparation of blueprints to guide the further evolution of the NCP and participated in the management committee to determine funding priorities and to evaluate proposed research projects.

Council for Environmental Co-operation
ICC Canada helped Barry Commoner and co-researchers at the City University of New York prepare a dioxin transportation and deposition project in Nunavut. This $80 000 project is funded by the Montreal-based Council for Environmental Co-operation.

Funding
In September 1998, ICC Canada was awarded a two-year $200 000 grant from the Walter and Duncan Gordon Foundation to carry out international contaminants and Arctic Council work at both the political and staff levels. This grant, coupled with money received from the NCP, ensures the continued operation of ICC Canada's environment department.

Communication in the North
ITC is submitting a report on communication activities and involvement of Inuit regions in the NCP. ICC Canada has been an active participant in these meetings, particularly at a political level involving the boards of the regional Inuit associations. ICC Canada has recently instituted an English/Inuktitut journal dealing with public policy issues os interest and relevance to Inuit. The first issue is enclosed. The second issue, scheduled for July, deals with the Arctic Council, and the third issue, likely available in October, will deal with transboundary contaminants and global negotiations.

NORTHWEST TERRITORIES ENVIRONMENTAL CONTAMINANTS COMMITTEE

Project Leader: Carole Mills, Chair, NWT ECC, Contaminants Division, DIAND-NWT

Project Team: Representatives from Dene Nation; Métis Nation -NWT; Inuit Tapirisat of Canada; Inuvialuit Game Council; Nunavut Tunngavit Inc.; Gwich'in Tribal Council; Sahtu Secretariat; Deh Cho First Nations; Dogrib Treaty 11; Akaitcho Territory Tribal Council; North Slave Métis; South Slave Métis; DIAND; Environment Canada; Department of Fisheries and Oceans; Government of Northwest Territories (GNWT) Resources, Wildlife, and Economic Development; GNWT Health; Aurora Research Institute; Nunavut Research Institute

OBJECTIVES

The Northwest Territories Environmental Contaminants Committee (NWT ECC) will facilitate the process of collaborative study, assessment and communication of information to Northerners about the presence and possible effects of contaminants in the air, land, water and wildlife. Its goals are:

1. To provide a forum for the two-way transfer of contaminants information between NWT Northerners, researchers, the Northern Contaminants Program (NCP) and other contaminants-related programs;
2. To establish a communications network that ensures Northerners are informed and involved in contaminant activities;
3. To identify priorities and information gaps related to environmental contaminants research in the NWT;
4. To act as a central repository for environmental contaminants information;
5. To provide advice on appropriate funding sources; and
6. To review NCP proposals from the NWT prior to full technical reviews.

DESCRIPTION

As the Northern Contaminants Program (NCP) has evolved to include NWT communities and regions extensively in research and communication efforts, the need to have a central body that can coordinate contaminants information and research initiatives has increased. The NWT ECC provides a one-window opportunity for researchers and communities to provide input into contaminants activities and express their concerns.

The membership is composed of key northern organizations and government departments, making it particularly suitable for addressing NWT research priorities and information gaps. The Committee provides an initial review of proposals involving the NWT, by determining whether or not proposals address an NWT research priority or information gap, whether similar work has been done before, and whether or not the consultation process is adequate.

ACTIVITIES IN 1998/1999

The NWT ECC met six times to discuss various contaminants-related issues (Table 1). Among its key activities was hosting the Eastern Arctic Contaminants Workshop, December 3–5, 1998 in Iqaluit. As requested by the NCP, the Committee conducted the social/cultural reviews for all NCP proposals that related to the NWT as well as the technical reviews for any communications-related proposals that involved the NWT.

RESULTS

Notes from the six meetings are available which summarize the activities of the Committee.

Table 1. Dates and type of meeting held by the NWT ECC.

Meeting Name	Meeting Date	Meeting Type
NWT ECC1	May 26, 1998	In person in Yellowknife
NWT ECC2	July 16, 1998	Conference call
NWT ECC3	September 3, 1998	Conference call
NWT ECC4	October 24, 1998	Conference call
NWT ECC5	December 6, 1998	In person in Iqaluit
NWT ECC6	February 9 - 11, 1999	In person in Yellowknife

DISCUSSION / CONCLUSIONS

The NWT ECC has proved to be an effective forum for discussing contaminants-related concerns and for providing northern input to the NCP. A major activity for 1999/2000 will be the re-organization of the Committee to reflect the creation of Nunavut.

Expected Project Completion Date: The NWT ECC expects to continue operating through the 1999/2000 fiscal year.

THE YUKON CONTAMINANTS COMMITTEE COMMUNICATIONS PROGRAM

Project Leader: Mark Palmer, Chair, Yukon Contaminants Committee

Project Team: Department of Indian Affairs and Northern Development (DIAND); Council for Yukon First Nations; Yukon College; Yukon Conservation Society; Yukon Territorial Government; Environment Canada; Department of Fisheries and Oceans

OBJECTIVES

1. To answer questions Northerners have on contaminants issues;
2. To communicate the results of work carried out under the Northern Contaminants Program;
3. To act as a link between researchers and stakeholders; and
4. To educate Northerners on contaminants issues.

DESCRIPTION

The Yukon Contaminants Committee (YCC) was established in 1992 to address contaminants concerns within the Yukon. The YCC acts as a link between the scientific community and Northerners. The core membership is diverse and consists of representatives from several federal and territorial departments, the Council for Yukon First Nations, Yukon Conservation Society and Yukon College. Individual First Nations have also played several key roles on the Committee.

The YCC coordinates the projects funded under the Northern Contaminants Program (NCP) in order to reduce overlap and to allow better coordination between researchers and Northerners. The majority of the Committee's operating budget covers travel costs to attend meetings and workshops in the Yukon and across Canada.

ACTIVITIES IN 1998/99

One of the biggest challenges facing the YCC is the education and communication of scientific information to Northerners. Prior to the release of any scientific information, it is essential to provide the public with the capacity to fully understand the information. In an attempt to accomplish this, the YCC has coordinated several information/education programs. A few examples (in addition to many informal telephone requests for information and smaller information sessions) include:

- Annual public workshops with representation from all Yukon First Nations
- Establishment of a contaminants library at Yukon College. This includes over 50 publications as well as over 200 journal articles
- A series of Yukon Fact Sheets covering topics such as PCBs, DDT, toxaphene, metals (general), mining, and cadmium
- YCC meetings approximately 4-6 times per year
- Providing funding for developing an Environmental Chemistry course at Yukon College
- Development of curriculum material for Yukon schools, grades 2-12

FUTURE DIRECTIONS

The YCC will continue to act as the Yukon's link to the broader national/international elements of the Northern Contaminants Program. Membership will remain diverse and will expand when required to represent all northern stakeholders. If an individual would like additional information please call 867-667-3282.

NORTHERN CONTAMINANTS PROGRAM INTERLABORATORY QUALITY ASSURANCE PROGRAM

Project Leader: Yvonne D. Stokker, Environment Canada, National Water Research Institute (NWRI), Burlington, ON

Project Team: Ed Kaminski, NWRI; Glynn Gomes, Gomes Consulting Enterprises; Johan van Hoewelingen, Hogeschool van Utrecht, The Netherlands; members of the Northern Contaminants Program (NCP) Quality Assurance Subcommittee; all measurement laboratories in the NCP.

OBJECTIVES

Short-term

1. To conduct intercomparison exercises on various contaminants of concern, such as persistent organic pollutants, radionuclides and heavy metals, in order to:
   a) ensure laboratories conducting measurements for the NCP are producing reliable data with acceptable levels of precision and accuracy;
   b) ensure comparability between laboratories; and
   c) provide a diagnostic tool for the measurement laboratories of the NCP to apply corrective measures, as needed.
2. To propose, coordinate and review participation by NCP measurement laboratories in external national and international interlaboratory comparison exercises where such participation would be considered to be more cost-effective and where it would add value to the NCP Quality Assurance (QA) program.

Long-term

1. To maintain up-to-date information on the analytical programs and capabilities of the laboratories and organisations that contribute measurement data to the NCP.
2. To design and conduct a program that delivers a series of appropriate interlaboratory comparison studies that will provide the NCP research project leaders, ongoing assurance of the quality, reliability, and comparability of measurement results produced by laboratories contributing data to their NCP research studies.
3. To conduct surveys, interlaboratory study assessments and external intercomparison reviews to identify sources of measurement uncertainties and variation among analytical results to provide information on overall data quality and reliability to the Management Committee of the NCP.

DESCRIPTION

The Northern Contaminants Program (NCP), like all research and monitoring programs, requires an ongoing quality assurance (QA) program that provides assurance to its managers of the quality, reliability and comparability of measurement results being generated for their research projects. At the same time, it should meet the diverse quality assurance and quality control (QA/QC) needs of the researchers and analysts by providing them with appropriate diagnostic tools for their analyses and offering guidance and support toward corrective measures, if needed. This interlaboratory QA program of the NCP aims to identify sources of measurement uncertainties and variation of analytical results in order to provide information on data quality to the management of the NCP.

This past year saw a shift in focus within the NCP from the Phase I interest in pathways, trends and controls of contaminants in the Arctic environment to the Phase II interest in human health and safety issues associated with contaminants in traditionally harvested foods for Northern people. As a result, the initial 1998/99 activities of the QA program focussed on identifying the measurement laboratories that contribute analytical data to the NCP, and specifically where their interests and capabilities lie.

NCP-funded research and monitoring studies involve the analysis of a wide variety of contaminants at trace and ultra-trace levels in various matrices including air, snow, water, sediments, plants, fish, mammals and human tissue samples. It is such a diverse program that the question of comparability of data among the different measurement laboratories and between individual projects becomes difficult to assess. Ideally, a carefully designed QA program would ensure the reliability and comparability of analytical results for all target contaminants in each matrix and species, as well as among the individual laboratories contributing the measurement data. Unfortunately, such a broad scope of activities would be too costly. Consequently, a survey of national and international external interlaboratory study providers was undertaken to determine where participation in external intercomparisons would be more cost-effective to the NCP QA program while still providing adequate assurance of NCP data quality.

Because the NCP-funded projects target contaminants in many different matrices and species, there is no single matrix sample that would be suitable for evaluating all participating laboratories. One way to accommodate such diversity is to include check samples prepared in solution form. Intercomparison study participants should then use their own routine methodology and analytical calibration standards. This interlaboratory QA program has been designed to incorporate a variety of natural materials in future interlaboratory studies, in order to achieve an increasing progression of complexity in the test samples. In addition, a small repository of surplus samples with known target parameter concentrations will be made available to NCP laboratories that experience difficulties with the study samples and therefore require additional test material to evaluate the success of their corrective actions.

The submitted laboratory data for both the standard solutions and matrix test samples are evaluated for accuracy and comparability by Z-scores and by comparison to the target concentrations, for precision on replicate analyses (or by percent difference on blind duplicate samples), and for bias by a modified Youden ranking procedure. The data assessment is then used as a diagnostic tool for the participants to apply corrective action, if needed. Finally, the complete study report provides a snapshot of data quality to the Management Committee of the NCP along with an overview of the capabilities and comparability of the NCP laboratories conducting these measurements.

ACTIVITIES IN 1998/99

The QA program of Phase II of the NCP began with a survey of the project leaders and the laboratories conducting analyses for the NCP (i.e. using NCP funds) (Stokker and Gomes 1998). The purpose of the survey was to identify the laboratories conducting NCP-funded measurements and compile information on their analytical capabilities as well as to determine the relevant matrices, analytes and contaminant levels for the quality assurance program. The resultant inventory of laboratories and measurement analyses was then used to determine current QA needs and to prioritize future NCP QA activities.

A second (concurrent) survey of external national and international QA programs was conducted to identify external intercomparison studies that would complement those run in the NCP QA program (Stokker and Gomes 1999). This survey assessed the suitability of each external QA program in terms of parameters and concentration levels, test sample matrix, cost, and timing and frequency of the studies. In making recommendations on the use of these external programs to support the NCP's QA needs, additional factors, such as the number of NCP-funded laboratories for which these external intercomparisons would be appropriate, were also considered.

At the request of the QA Technical Subcommittee, efforts were also directed this year at developing a list of PCB congeners that could be made mandatory for all NCP-funded PCB analyses. A small database was compiled for PCB congeners reported in the literature for various marine or Arctic matrices. The selection of congeners was based on their toxicity, frequency of occurrence and concentration levels relative to the (reported) Total PCB levels. Comparisons were made to existing PCB congener lists in other external research and QA programs. The proposed NCP list of PCB congeners will be forwarded to the measurement laboratories for comments and to the QA Technical Subcommittee for their review.

The first intercomparison study for Phase II of the NCP (Interlaboratory Study NCP-II-1) was conducted on the analysis for trace metals in sediment. While the study focussed on the key elements of mercury, selenium and cadmium, the participants were only obliged to analyse and report on the analytes of interest to their respective projects. Eight laboratories provided results, and most participants analysed for at least 10 of the 16 target parameters.

RESULTS

Survey 1. The information for the first survey report (Stokker and Gomes 1998) was gathered via a written questionnaire that sought information on contact persons, analytical capabilities of the laboratories, analytes, concentration levels and matrices, methodologies and instrumentation, the use of certified reference materials (CRMs), and participation in any external interlaboratory studies. The survey questionnaire was sent to more than twenty project leaders who were identified as receiving NCP funding.

For 1998/99, the number of NCP measurement laboratories conducting analyses on the various sample types were as follows:

various biotic samples	19
fish	13
water	18
sediment/soil	13
human food stuffs	4
animal feed	2
snow	4
urine	6
blood	6
mining products and effluents	4

Thus, biotic samples of one form or another were the most commonly analysed matrix material, with water and sediment samples also being quite common among the laboratories surveyed.

The survey also identified the number of laboratories conducting analyses for the different contaminants of interest to the NCP as follows:

trace metals	12
mercury	13
methylmercury	2
organotins	2
radionuclides	6
nutrients (in water)	4
organochlorine pesticides (OCs) and PCBs	16
toxaphene	8
dioxins and furans	8
polynuclear aromatic hydrocarbons (PAHs)	4
brominated diphenyl ethers (BPDEs)	1

Clearly, there are sufficient NCP laboratories to justify conducting a series of intercomparison studies for OCs/PCBs, toxaphene, dioxins and trace metals. However, for nutrients in water, PAHs, organotins, and methylmercury, where fewer than five NCP laboratories conduct such analyses, a closer scrutiny of available external options would help to determine the most effective means of assuring the quality and intercomparability of these NCP measurements.

Survey 2. The questionnaire for the second survey sought to identify available external intercomparison studies that would complement the NCP QA program by bridging gaps, particularly for those parameters listed above, where fewer than five NCP laboratories would be involved.

The survey (Stokker and Gomes 1999) revealed that participation in the following external QA programs would enable the NCP QA program to assess data quality for a much broader range of analytes and matrices than could be covered by the NCP intercomparisons alone:

a) QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring in Europe, FRS Marine Laboratory, Aberdeen, Scotland), particularly for its toxaphene and organotin development exercises,

b) CAEAL (Canadian Association for Environmental Analytical Laboratories, Ottawa, ON) and NWRI for nutrients in water;

c) the NOAA (National Oceanic and Atmospheric Administration, Silver Spring, MD) program for trace metals in sediment and biota run by the National Research Council of Canada;

d) the IAEA (International Atomic Energy Agency, Vienna, Austria) intercomparison exercises for radionuclides, and when available, for organotins and methylmercury; and

e) the blood and urine intercomparison studies conducted by the Centre de Toxicologie du Quebec (CTQ) or the Great Lakes Research Centre (Michigan, USA) for metals and PCBs, respectively.

Development of a list of 'mandatory' PCB congeners: A literature review was conducted on the PCB congener levels reported for samples from marine and Arctic origins. Tables of data have been compiled for each of the following matrices: water, air/snow/rain, vegetation, sediment, fish, mussels, mammalian and bird tissues, blood (human and seal), and other human tissue samples. When potential toxicity, environmental prevalence, and relative abundance in animal tissues are used as criteria, the number of environmentally threatening PCB congeners reduces to about thirty-six. Twenty-five of these account for 50-75% of total PCBs in tissue samples of fish, invertebrates, birds and mammals.

The proposed list has been compared to the Integrated Atmospheric Deposition Network (IADN) list, the list of POPs recommended for the Arctic Monitoring and Assessment Programme (AMAP), the Quebec Ministry of Environment congener mix, and the target congeners for external intercomparison studies offered by QUASIMEME, IAEA and NOAA.

Interlaboratory Study NCP-II-1. Trace metals in sediment. Eight laboratories provided trace metal results on the four sediment check samples. For most of the metals, the data were quite comparable, as demonstrated by coefficients of variation of less than 25%. The parameters that showed the least comparability were chromium, selenium and vanadium. The repeatability of analysis for each participant was quite good on the duplicate samples, with only one laboratory exceeding 10% difference between duplicates for more than one metal. All laboratories exhibited some bias for at least one of the target parameters. Z-scores for all key toxic metals were less than 2.

Overall, the results of the trace metals in sediment interlaboratory study (Stokker and Kaminski 1999) were in good agreement with previous trace metal assessments conducted by the NWRI on sediment samples, and are in keeping with assessments reported by QUASIMEME, IAEA and NOAA-NRC. A second intercomparison on trace metals in biota is currently being conducted.

DISCUSSION/CONCLUSIONS

Quality assurance and quality control are essential elements of all research and monitoring programs. Ongoing interlaboratory comparison studies provide assurance on the quality of data being generated and on the comparability of measurement results between laboratories. Without this assurance of data quality and comparability, the value of measurement information upon which decisions are made will be lost. It is imperative that managers and decision makers of the NCP have a scientifically sound science base upon which to base their decisions.

The two surveys (Stokker and Gomes 1998, 1999) identified some parameter/matrix combinations for which the quality of data is already being competently addressed by other QA programs. Examples are the CAEAL and NWRI studies for trace metals (including mercury) and nutrients in water, and the IAEA intercomparisons for radionuclide measurements. In addition, several of the larger facilities include participation in pertinent interlaboratory studies as part of their own quality management system. However, it also was evident that many of the smaller NCP measurement laboratories are not participating in any pertinent external QA programs. Furthermore, the availability of external intercomparisons for less common contaminants of interest, such as organotins and methylmercury, are infrequent and may not address the matrix or concentration levels necessary.

The current recommendations for the NCP interlaboratory QA program are:

a) to conduct interlaboratory studies for OCs/PCBs that specifically address parameters such as HCHs, chlordanes, and PCB congeners at appropriate levels in both biotic and abiotic samples,

b) to establish a series of intercomparison studies to monitor the quality of toxaphene data being generated, where external intercomparison studies are either not available or are not suitable to the work of the NCP laboratories,

c) to continue to address the data quality of trace metal analyses, including those for mercury, methylmercury and selenium, where feasible,

d) to make participation in an appropriate external Nutrients in Water QA program mandatory for the laboratories conducting such analyses,

e) to encourage participation by the radionuclide measurement facilities in the IAEA QA program, and

f) to address the comparability of measurements for analyses of organotins, dioxins and PAHs, as needed.

Thus, interlaboratory comparison exercises are, and will continue to be the main activities of this QA program. Other activities, such as a maintaining an inventory of laboratories and their capabilities, and a list of external sources of QA support such as intercomparisons and reference materials, are also important to achieve the goals of this program. The combination of these efforts will not only provide for an evaluation of data quality within the NCP, but will also provide a means for continual improvement in the measurement process for the laboratories involved.

Expected Project Completion Date: The two surveys (Stokker and Gomes 1998, 1999) were completed in January, 1998. As recommended by the QA Technical Subcommittee, an update of the laboratory survey will be provided annually prior to their review of the proposal for the next fiscal year's QA program.

The preliminary data review for the trace metals in sediment study was provided to the participating laboratories in April, 1999 and a report describing the full assessment of trace metal capabilities and comparability will be provided by September, 1999 (Stokker and Kaminski 1999).

The assessment of analytical comparability for other contaminants and matrices is an ongoing process, with two additional intercomparisons being scheduled for 1999/2000. The test samples for Interlaboratory Study NCP-II-2 on trace metals and methylmercury in fish and marine mammal tissue were delivered to participants in July, 1999; a final report will be provided to the participants by November, 1999. Interlaboratory Study NCP-II-3 on the analysis of persistent organic pollutants in fish is being targeted for September through December 1999, after the proposed list of mandatory PCB congeners is reviewed by the QA Technical Subcommittee.

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FACILITATION OF INTERNATIONAL ACTION RELATED TO LONG-RANGE TRANSPORT OF CONTAMINANTS INTO THE ARCTIC

Project Leader: David Stone, Department of Indian Affairs and Northern Development (DIAND)

Project Team: Northern Contaminants Program (NCP) Management Committee

OBJECTIVES

1. To facilitate international co-operation in determining the significance of long-range contaminant transport to Arctic peoples and their environment from sources outside of Canada.
2. To develop appropriate international controls on contaminant emissions and discharges.

DESCRIPTION

Persistent organic pollutants (POPs) from distant sources are transported to the Arctic mainly via the atmosphere. They accumulate in humans and in the Arctic food chain and reach levels of concern in many traditional food species important to northern Aboriginal people. The NCP was established to define the significance of observed levels, to provide information to Northerners on possible dietary health implications, and to support the development of appropriate international controls on the substances of concern.

The reduction and elimination of contaminant input to the Arctic requires comprehensive international co-operation and includes the following elements:

- The maintenance of the legally binding protocol on POPs negotiated under the Convention on Long-Range Transboundary Air Pollution (LRTAP) to apply in the region of the United Nations Economic Commission for Europe (UN ECE). This region covers much of the Northern Hemisphere;
- Facilitating and negotiating global actions on POPs to be applied by nations from outside of the geographic area defined by the LRTAP Convention;
- The Arctic Monitoring and Assessment Programme (AMAP), whose goal is to monitor the levels of, and assess the effects of, anthropogenic pollutants on all components of the circumpolar Arctic environment; and
- The Canada/Russia Program on Scientific and Technical Cooperation in the Arctic and the North; a program established to gather information from the Russian segment of the Arctic to understand the transportation pathways of certain contaminants from Russia into the Arctic.

ACTIVITIES IN 1998/99

1. UN ECE LRTAP Convention

The legally binding LRTAP protocol has now been successfully negotiated and was signed by 34 countries (including Canada) at the UN ECE Ministerial Conference in Aårhus, Denmark in June 1998. Canada ratified this agreement in December 1998. It will come into force as a legally binding document for those countries which have signed when it has collected 16 signatures. It bans or severely restricts the manufacture, use or loss to the environment of initially 16 substances, including all of POPs of concern in the Canadian Arctic. It includes a mechanism allowing for the later addition of more substances. A similar protocol controls the manufacture, use or loss of the heavy metals cadmium, lead and mercury.

2. Development of Action on POPs in Non-UN ECE Regions

In Montreal in June 1998, Canada hosted the first negotiating session to achieve global controls on POPs through a new Convention under the auspices of the UNEP. The second negotiating session, held in Nairobi January 1999, established a separate group to deal with implementation of the future agreement. The main issues which emerged were:

- determining the nature, extent and management of technical assistance which will be made available to developing countries as they move to eliminate their use of POPs;
- the need for differential obligations allowing certain developing countries to phase out their use of POPs over a longer time frame than will be allowed for developed countries;
- the need to gather information on levels of POPs in developing countries to convince them that to control POPs should be a domestic priority for their governments; and
- whether it will be necessary to include trade restrictive measures if both production and use of POPs is eliminated.

A second Southeast Asia workshop to help developing countries prepare for UNEP negotiations took place in March 1999 and was partially supported by NCP 1998/1999 funding. The meeting focused on capacity building in developing countries and on developing inventories of POPs with a potential for environmental release. Southeast Asia has been targeted since this region is believed to be a significant source of POPs emissions and discharges. However, these activities have confirmed that the challenge of achieving global controls on POPs will be to ensure that developing countries have the capacity to comply with any future POPs actions.

Moving the agreement into action will present a very difficult challenge for most developing countries where POPs are still heavily utilized. Negotiations are expected to run for at least three years (completion date expected by 2001).

3. Arctic Monitoring and Assessment Programme (AMAP)

Canadian activities concentrated on assisting in the design of the second phase of AMAP. Canada and Sweden prepared a proposal for draft framework for monitoring POPs. Other countries undertook the lead to develop proposals on other topics (e.g. heavy metals, human health, radioactivity, hydrocarbons, the effects of climate change and ultra-violet radiation, etc.). The AMAP Working Group decided that, although these proposals require further work, a sufficient basis of information existed for countries to submit their "national implementation plans". These plans constitute a country's commitment to undertake the proposed work. Canada was one of the countries which submitted a national implementation plan which consisted of the NCP Blueprints supplemented with a listing of NCP projects funded in the fiscal year 1998/1999.

4. Canada/Russia Program on Scientific and Technical Cooperation in the Arctic and the North

In 1998, AMAP initiated a project aimed at assisting Russia sign and ratify the LRTAP Convention POPs protocol. This project consists of starting an inventory of PCB use and stockpiles in western Russia. This work would form the basis for preventative and remedial action plans and identification and utilization of alternatives, and for applications to aid agencies that have already expressed interest in this project. At the conclusion of negotiations, Russia stated that its dependence on PCBs for electrical transmission purposes precludes their commitment to a ban on production of these substances.

A joint Canada/Russia/AMAP project to establish and operate a second air monitoring station at Amderma in Russia's western Arctic region was finalized in March 1999. The Russian partner is Typhoon, an institute under ROSHYDROMET, located at Obninsk. They will operate the site for a two-year period from May 1999 to September 2001. The Canadian agency coordinating the overall project is Conor Pacific at Downsview, ON (contact: Phil Fellin) in association with DIAND (contact: Russel Shearer), the Canadian International Development Agency (CIDA) and the Atmospheric Environment Service (AES) (contact: Keith Puckett) and AMAP (contact: Lars-Otto Reiersen). The samples will be analysed by the Department of Fisheries and Oceans' Freshwater Institute in Winnipeg (contact: Gary Stern) and by Typhoon (contact: Dave Thomas, AXYS Group, Victoria, BC).

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